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Research Report 1806

Using Virtual Environments for Conducting Small Unit Dismounted Mission Rehearsals

Robert J. Pleban
U.S. Army Research Institute

Jena Salvetti
Consortium Research Fellows Program

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ZITA M. SIMUTIS
Director

Technical review by

Bruce W. Knerr, U.S. Army Research Institute
Jean L. Dyer, U.S. Army Research Institute

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14. ABSTRACT *(Maximum 200 words)*:

This research examined the use of virtual environments as a viable dismounted infantry mission rehearsal tool. Four squads of soldiers individually conducted two missions that involved clearing a two-story building located at an urban operations training site. Two squads rehearsed the mission in a virtual representation of the exact building they would clear at the urban training site. The remaining squads rehearsed in an actual two-story building that was similar to the one they would clear at the urban training site. Squads executed both missions in each environment. Performance differences between the rehearsal groups across the two 'real-world' missions were small to negligible. Group performance differences for fratricides and personnel flagging were negatively affected by simulator constraints. Effectiveness ratings for the two rehearsal modes were clearly dependent on the setting where soldiers rehearsed. The research showed that while virtual environments show promise for this type of training, a number of interface and technology problems must be overcome. Currently, virtual environments do not appear to be as effective as real-world tactical training for improving skills underlying specific small unit tasks or battle drills. However, these environments may be used effectively at selected stages of training to enhance cognitive skills development.

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Robert J. Pleban
U.S. Army Research Institute

and

Jena Salvetti
Embry-Riddle Aeronautical University
Consortium Research Fellows Program

Infantry Forces Research Unit
Scott E. Graham, Chief

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

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FOREWORD

This report describes selected aspects of the fourth year work effort under the Science and Technology Objective (STO) entitled *Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal*. The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Infantry Forces Research Unit performed this research in collaboration with the ARI Simulation Systems Research Unit, the U.S. Army Simulation, Training, and Instrumentation Command, and the U.S. Army Research Laboratory. The primary objective of the STO was to address selected technological and training issues related to high fidelity dismounted soldier simulation.

This report describes a research effort that examined the utility of virtual environments for conducting small unit dismounted mission rehearsals in simulated urban operations. The training was evaluated at the Dismounted Battlespace Battle Lab (DBBL) Virtual Simulation Lab, and the McKenna urban operations facility at Fort Benning, Georgia. The effectiveness of this approach was compared to real-world rehearsals. The results showed that while virtual environment systems show promise, there are still a number of interface and technology problems to overcome. Currently, virtual environments do not appear to be as effective as real-world tactical training for improving skills underlying specific small unit tasks or battle drills. However, these environments may be used effectively at selected stages of training to enhance cognitive skill development in such areas as decision-making and situation awareness. Critical aspects of the research were briefed to key DBBL staff in August 2002.

KATHLEEN A. QUINKERT
Acting Technical Director

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We would also like to thank Second Lieutenant Charles Schwab for his overall support of this research. Lieutenant Schwab served as one of the squad members in the experiment. He was also responsible for conducting the majority of the statistical analyses involving the squad assessment data. His assistance in these areas was greatly appreciated.

USING VIRTUAL ENVIRONMENTS FOR CONDUCTING SMALL UNIT DISMOUNTED MISSION REHEARSALS

EXECUTIVE SUMMARY

Research Requirements:

Soldiers and small unit leaders (platoon, squad, team) must be capable of taking effective independent actions across an increasingly diverse range of military missions. The time and resources required for conducting the appropriate training in realistic, live exercise settings can be quite costly and also inefficient for certain skill areas (e.g., cognitive skills training). One solution is to conduct a portion of this training in virtual environments using individual combatant simulators. The objective of this research was to assess the use of virtual environments as a viable dismounted infantry mission rehearsal tool. Two research questions were addressed:

- Do skills acquired in the virtual environment transfer to the real world?
- How does real world performance differ as a function of rehearsal training site?

Procedure:

Thirty-two soldiers (four squads) received instruction on urban operation tactics, techniques, and procedures. Each squad was then given two missions that involved clearing a two-story building located at an urban operations training site. Two squads rehearsed (and executed) the mission in a virtual representation of the exact building they would clear at the urban training site. The remaining squads rehearsed in an actual two-story building that was similar to the one they had to clear at the urban training site. Squad and individual performance was objectively assessed by two observer/controllers for each mission. Soldier responses to the training and evaluations comparing the effectiveness of the two rehearsal settings were obtained.

Findings:

Performance differences between the rehearsal groups across the two 'real-world' missions for both squad and individual tasks were small to negligible. Group performance differences for casualties, i.e., fratricides, and personnel flagging (silhouetting oneself in doorways and windows) were strongly affected by simulator constraints that made it very difficult to execute precision movements in confined areas and effectively throw hand grenades. The results showed that virtual environment rehearsal did not hurt real-world performance, but were equivocal as to how much transfer did take place. Soldier effectiveness ratings for the two rehearsal modes showed a clear bias that was dependent on the setting where they rehearsed. Half of the soldiers who rehearsed in a virtual setting felt that virtual environments were just as effective for conducting mission rehearsals as rehearsing in the real-world. In contrast, all

soldiers who rehearsed in the real-world felt that virtual environments were inferior to real-world rehearsals.

Utilization of Findings:

This research showed that the effectiveness of virtual environments for conducting small unit dismounted mission rehearsals is limited by a number of interface and technology problems. These shortcomings make it difficult to train specific squad drills and tasks, like building clearing, which emphasize rapid and precise positioning and movement and use of weapons. While virtual environments show promise for this type of training, they do not appear to be as effective as real-world tactical training at the present time. Virtual environments could, however, be effectively used during the "walk" phase of training for improving decision-making, situation awareness, communication, and coordination skills. These environments, if used in conjunction with realistic field exercises, could play a major role in enhancing the training of soldiers and small unit leaders.

USING VIRTUAL ENVIRONMENTS FOR CONDUCTING SMALL UNIT DISMOUNTED MISSION REHEARSALS

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USING VIRTUAL ENVIRONMENTS FOR CONDUCTING SMALL UNIT DISMOUNTED MISSION REHEARSALS

Introduction

Current Army transformation initiatives will require increasingly innovative methods for training soldiers and small unit leaders (platoon, squad, team). Leaders, for example, must be able to effectively lead multifunctional units, use digital systems, and conduct decentralized and dispersed operations across the full-spectrum of possible missions. Preparing soldiers for the diversity of missions and skills required to effectively operate in these situations will present many challenges to trainers.

The time and resources required for conducting the appropriate training in realistic, live exercise settings can be quite costly and inefficient, particularly for the specific leader skills needed for such operations (see Pleban, Eakin, Salter, & Matthews, 2001). To develop and sustain the tactical and technical proficiency required in these varied situations, tools are needed that can provide (in a cost effective manner) frequent and repetitious complex task training across diverse scenarios.

One potentially useful training tool that has received considerable attention involves the use of virtual simulations, specifically, individual combatant simulators. A virtual training system can be particularly useful for "walk-level" and sustainment training (Pleban et al., 2001). Virtual training not only provides the capability to immerse soldiers in a realistic operational environment, but this training can be accomplished without risking the safety of soldiers, breaking expensive equipment, or potentially polluting or destroying the environment. Virtual training also allows soldiers to perform tasks too dangerous for the live environment such as conducting close quarters combat, operating in NBC environments, and adjusting artillery or close air support fires on or near an occupied friendly position. The virtual environment (VE) provides a primary means for units to frequently and repetitively train realistic fire and maneuver techniques (TRADOC System Manager Combined Arms Tactical Trainer, 2002). Virtual environments can be effectively applied to enhance small unit leader skill training in decision-making (Pleban et al., 2001), and may have training value in other areas such as operational planning, command and control of small units, direct fire coordination, fire support coordination, and integration of obstacles and logistical support.

At the Virtual Simulation Lab at Fort Benning, Georgia, the individual soldier or small unit leader can explore innovative approaches for conducting specific tactical operations in virtual settings. Through the use of individual combatant simulators, soldiers can immerse themselves in virtual representations (using terrain data bases) of various training sites such as the McKenna urban operations site at Fort Benning and conduct limited missions (e.g., clear a building, conduct area reconnaissance). Virtual environments, in theory, offer soldiers the opportunity to thoroughly familiarize themselves with procedural aspects of specific tasks as well as a chance to examine new tactics and techniques. These simulators allow the soldiers to execute scenarios and determine the impact of various courses of action on the likely success of a mission (Pleban, Eakin, & Salter, 2000).

One of the best performing of the currently existing individual combatant simulation systems is the Soldier Visualization Station - SVS (see Salter, Eakin, & Knerr, 1999) developed by Advanced Interactive Systems. This system represents the currently most viable overall technical approach for enabling soldiers to shoot, move, and communicate in virtual environments. In this system, the soldier stands in front of a large screen holding a rifle. The images depicted on the screen, including buildings, vehicles, and people, are reasonably life like in size and actions. The combination of images and action creates a very immersive (virtual) environment for the soldier (see Figure 1).

The SVS is a personal computer-based system with an inertial/acoustic tracker for simulated body position and weapon pointing. It includes a helmet-mounted display - HMD (helmet mounted monocular eyepiece linked to a camera on the rifle) that can be used to assist in aiming and looking around corners of buildings. The SVS has one flat screen on which images are presented by a rear projection device. Movement is accomplished by applying pressure to a weapon-mounted thumb switch. This allows the individual to move rather effortlessly throughout the virtual battlefield to include open terrain and urban environments. The thumb switch also controls access to an on-screen menu that allows the individual to select among various weapons, e.g., M-4 rifle, squad automatic weapon, shotgun, pistol, grenades, smoke, and includes a program for weapon zeroing.

Figure 1. Soldier in an SVS system.

Science and Technology Objective (STO) Virtual Environment Research

In 1998, the U.S. Army Research Institute (ARI) established a four-year Science and Technology Objective (STO) entitled Virtual Environments for Dismounted Soldier Simulation Training and Mission Rehearsal. The purpose of the STO was to examine selected technological and training issues that currently limit high fidelity dismounted simulation (see Pleban et al., 2000). A collaborative STO effort was established between the Infantry Forces and Simulation Systems Research Units of the ARI, the U.S. Army Simulation, Training, and Instrumentation Command, and the Human Research and Engineering and Information Sciences and Technology Directorates of the U.S. Army Research Laboratory to address these issues. The ARI portion of the STO was covered under the work package Virtual Environment Research for Infantry Training and Simulation (VERITAS). Key VERITAS work objectives included the following:

- Identify potential high payoff tasks for small unit leader virtual environment (VE) training
- Evaluate small unit training vignettes for use in infantry urban operations training
- Develop training strategies and performance measures
- Evaluate the training effectiveness of simulation systems
- Evaluate the use of VE for night operations training

The research addressing each of these objectives is thoroughly described in Pleban et al. (2000), Pleban et al. (2001), and Pleban and Beal (2002). Two key findings that emerged from this research were the utility of virtual simulation systems for conducting decision-skills training (Pleban et al., 2001) and mission rehearsal activities (Pleban et al., 2000). Empirical data in support of the mission rehearsal function of virtual environments were severely limited, however. In the Pleban et al. (2000) experiment, soldiers rehearsed a building-clearing mission in an exact virtual representation of the McKenna urban operations training site and subsequently executed multiple versions of this mission at the actual McKenna site. Funding restrictions precluded the use of a baseline or control condition that involved rehearsing in a more traditional field setting. The feedback provided from the soldiers (though entirely subjective), indicated that the virtual environment rehearsals had improved their performance on many of the same tasks executed at the McKenna training site. Soldiers also indicated that these virtual rehearsals minimized on-site planning time since they were already familiar with the interior layout of the buildings and helped mentally prepare squad members for the upcoming mission. The research objective during the final year of the STO work effort was to conduct a more comprehensive evaluation of the use of virtual environments as a viable dismounted infantry mission rehearsal tool.

Virtual Environments for Mission Rehearsal

Simulations, particularly flight simulator systems, have been used extensively in aviation settings to familiarize and train pilots in the operation of a particular aircraft. However, with the advent of powerful digital terrain database generation capabilities, accurate representations of specific, real-world areas could be created. The pairing of high-end simulation with high fidelity terrain database generation capability represented an evolutionary change in flight simulation technology. Now, crews could not only be trained on specific aviation task functions, but they

could also rehearse an upcoming mission in a tactical environment similar or identical to the one they would encounter in the real world (Nullmeyer & Spiker, 2000). Through the use of networked simulators, an entire operational team (ground forces, additional aviation systems, command and control group) can interact with each other and rehearse as a coordinated element.

There are advantages to this type of rehearsal approach. First, the mission plans can be validated using live players. Second, tactics can be refined and improved prior to the actual mission. Third, unit members, having executed the virtual mission, should be more prepared and confident of their abilities. Finally, command and control elements should have a clearer understanding of potential battlefield dynamics and risks (Nullmeyer & Spiker, 2000).

The concept of simulation-based mission rehearsal represents a potentially powerful training tool. Due to the recency of this application, there is little direct research documenting the effectiveness of virtual environment mission rehearsal in either aviation or dismounted infantry settings.

The available research has shown that virtual environment mission rehearsal has been effectively used, for example, to improve pilots' understanding of mission plans [Nullmeyer, Bruce, Conquest, & Reed, 1992); enhance subsequent use of available flight time (Lintern, Sheppard, Parker, Yates, & Nolan, 1989); improve target detection of objects at greater ranges (Krebs, McCarley, & Bryant, 1999) and; enhance route knowledge within buildings (Witmer, Bailey, Knerr, & Parsons, 1996). Virtual environments were also found to be as effective as more traditional rehearsal strategies, i.e., map-study, with regard to training navigational accuracy (Williams, Wickens, & Hutchinson, 1994).

Strategies for Effective Rehearsal

Direct evidence that details how to best use these simulation systems to conduct effective mission rehearsals is also limited. To maximize the effectiveness of virtual environment systems for conducting mission rehearsals, Nullmeyer and Spiker (2000) present a number of learning and instructional principles that trainers should consider when developing specific virtual environment rehearsal strategies. Some of these principles are discussed in the following sections.

Encoding. For rehearsals to be effective, the individual must internally encode the key behaviors or tasks to be trained. Research has shown that visually replaying the task or mentally rehearsing the steps involved in doing a task, e.g., karate moves, shooting free throws, rotary pursuit tracking, typing, guitar and vocal performance etc. has a positive but (sometimes) modest effect on subsequent performance (see Nullmeyer & Spiker, 2000). Driskell, Copper, and Moran (1994) conducted a meta analysis of 35 studies on mental practice. They found that mental practice is an effective but weaker means for enhancing performance than overt, physical practice. This type (mental) of practice is particularly effective for enhancing performance on cognitive tasks but the positive effects of mental practice declines over time. Finally, experienced subjects benefit equally well from mental practice regardless of task type, while novices benefit more from mental practice on cognitive tasks.

Practice. The rehearsal of specific behavioral or cognitive responses over time provides individuals with an opportunity to hone the skills and behaviors needed in the operational or criterion environment. In general, the longer the duration of practice, the better the performance. This finding has been documented over such varied tasks as visuo-motor behavior, word retention, theater, and chess (see Nullmeyer & Spiker, 2000). Driskell, Willis, and Copper (1992) found that overlearning is an effective means of enhancing subsequent performance, but only if the task that is overlearned is the task called for in the criterion performance setting. Overlearning also appears to be an effective training strategy for both physical and cognitive tasks. However, its impact is somewhat stronger for cognitive tasks.

While overlearning is generally associated with enhanced performance, there is the possibility that extended practice can lead to a loss of focus or concentration (Driskell et al., 1994) and stereotypic, rigid responding (see Nullmeyer & Spiker, 2000). This can be particularly problematical when conditions in the mission environment are fluid and uncertain. This suggests that trainers should have individuals practice the same mission but under varying scenarios that require them to discern key differences in the situation(s) and respond accordingly. In these instances, extended practice will help refine core, mission critical skills and also help develop mental schemas (or blueprints for how to respond) that will allow them to rapidly interpret the situation and respond in an appropriate manner (see Klein, 1997).

The type of practice can also have a major impact on performance, particularly in a typical mission rehearsal context where the unit(s) must master multiple tasks. In this context, distributed practice tends to be superior to massed practice (Schmidt & Bjork, 1992) and self-paced practice is more effective than fixed-paced (Swezey & Llanerus, 1997).

Feedback. Feedback can either be external or internal. External knowledge of results has been shown to improve performance in virtually every domain studied (Salvendy, 1997). Knowledge of results is more effective when it provides some form of directional information (fast/slow, left/right) than purely evaluative (good/bad) [Annett, 1989]. For individuals, internal (i.e., kinesthetic) feedback can significantly enhance the acquisition of motor skills beyond that offered by external knowledge of results (Swezey & Llaneras, 1997).

In general, for feedback to be most effective, it must be accurate, timely, credible, and constructive (Campbell, 1988). Feedback that is inconsistent, erroneous, and delayed can significantly decrease response accuracy and increase response time (Swezey & Llaneras, 1997).

As noted by Nullmeyer and Spiker (2000), mission rehearsal in military applications is an observable, group event in which information sharing and joint decision-making are vital. Some research has shown that external, collective feedback is optimal in such situations (Pearson, 1991). A major advantage of this feedback approach is that it can facilitate the development of shared mental models that allows all individuals to share a common internal knowledge base, increasing the likelihood that team members can anticipate problems and respond in a coordinated manner (Orasanu & Salas, 1993).

Direct focus of mission rehearsal sessions. The mere presence of an expensive, high fidelity simulator, does not mean that these systems will be used effectively. Mission rehearsals should focus on relevant task functions that are critical to mission success and which can be rehearsed in a 30 to 60 minute block of time (Nullmeyer & Spiker, 2000). The scenarios should include appropriate mission specific information that will enhance the cognitive processing capabilities of the participants in such areas as self/situation awareness, problem solving, and planning (Nullmeyer & Spiker, 2000).

Structure mission rehearsals to promote decision-making and shared understanding. The execution of any tactical mission is a team effort. Accordingly, the mission rehearsal setting should incorporate techniques that enhance group performance. Particular attention should be directed to improving decision-making skills since mission outcome is often the function of a series of complex decisions. Klein (1993) stresses the importance of situational assessment and the experience of the decision-maker in evaluating the shortcomings of a course of action. These factors can be systematically addressed in a series of well-crafted scenarios. Pre-executing the mission in a realistic rehearsal environment gives the leader and team members an opportunity to address relevant decision issues in the context of the specific mission to be accomplished. Together, with the appropriate feedback, simulation-based rehearsals should help participants establish more accurate expectations concerning the planned course of action, identify key decision points, and better prepare them to operate under time limited and stressful conditions.

Research Questions

The primary objective of this research was to compare the effectiveness of rehearsing for a mission in a virtual environment versus rehearsing in a real-world (RW), i.e., field setting. There were two key research questions: 1) Do skills acquired in the virtual environment transfer to the real world? and 2) How does real-world performance differ as a function of training (rehearsal) site?

Resource constraints required certain compromises. Frequent deployments and increasing commitments made it particularly difficult to find soldiers in sufficient numbers. This was compounded by the fact that performance assessment was based on the squad's actions which severely reduced the sample size. (Individual performance was assessed in a squad context.) The number of rehearsals were also truncated due to cost limitations. Wherever possible, the structure of the rehearsals were crafted to maximize learning and to enhance transfer of training effects. More specifically, rehearsal sessions were followed by timely, constructive feedback. Rehearsals were generally short (less than 30 minutes) and designed to promote leader and squad member decision-making and situational understanding.

Method

Overview

Soldiers received a brief block of instruction on urban operations tactics, techniques and procedures. Training was conducted by a retired non-commissioned officer with extensive experience in urban operations. Soldiers, acting as a squad element, executed two missions.

Both missions involved clearing a two-story building. For this experiment, a large section of one building was divided in half. The missions involved clearing each half of the building. The floor plans for each section of the building were similar (see Appendix G). A small opposing force (OPFOR) element was positioned in specific rooms within the building.

Soldiers in the VE rehearsal group first rehearsed the missions in a virtual representation of the exact building sections they would clear at a real-world field-training site. These rehearsals were conducted without an OPFOR. The VE rehearsal group then rehearsed the missions in the virtual environment with an OPFOR. More specifically, the VE group rehearsed (talk-walk and run) without an OPFOR in one building section then rehearsed again with an OPFOR in the same section. They then rehearsed (talk-walk and run) the second mission without an OPFOR in a different building section and then rehearsed again with an OPFOR in the very same section. The RW rehearsal group rehearsed in an actual two-story building that was similar to the one they would have to clear at the field-training site. Rehearsals for this group were conducted without an OPFOR.

Two retired Army personnel served as observer/controllers (O/Cs) and conducted the After Action Reviews (AAR) following each mission. They also provided assessments of the squads' performance for each mission.

The full experimental design is presented in Table 1. The VE rehearsal group received six rehearsal trials. Four rehearsals [talk-walk (2) and run (2)] were conducted without OPFOR. Two rehearsals were performed with an OPFOR. The RW rehearsal group received two rehearsal trials without an OPFOR. This disparity in rehearsal opportunities between the two groups was the result of several factors. First, from a logistical standpoint, it was not possible to rehearse the VE group at the Virtual Simulation Lab and transport everyone to the urban operations site to conduct the real-world missions in the same day. The set up and preparation required for the McKenna phase dictated that the VE training session be divided over two days. While it was possible to limit the VE rehearsals to the same two (talk-walk and run) trials without troops that the RW rehearsal group received, this option was rejected. This approach underutilizes the virtual environment capabilities. Previous experience with the SVS systems had indicated that soldiers quickly get bored moving around inside a virtual building without any type of force-on-force engagements with either a live or computer-generated OPFOR.

Given the increased training incentive from using live OPFOR (Pleban et al., 2000), and the ease of setting up and running virtual scenarios, it was determined that a fairer test of VE capabilities would be to allow soldiers to rehearse without soldiers (talk-walk and run) in virtual environment settings identical to those they would encounter the following day (one talk-walk and run rehearsal in each setting). In addition, soldiers would also receive one full rehearsal with a live OPFOR in a virtual environment identical to each setting they would encounter the following day (two full rehearsals). This also exploited another advantage of virtual rehearsals, i.e., the ability to generate a low cost, realistic simulation of the operational setting that will be encountered by the unit.

As can seen from Table 1, the RW rehearsal group was brought to the Virtual Simulation Lab on Day 2 for "supplemental" training. This was done to give this group experience in the

virtual environment and to allow them to make comparisons between the two rehearsal environments.

Table 1
Sequence of Events for Virtual-Environment (VE) and Real-World (RW) Rehearsal Conditions

Event	Rehearsal Condition	
	Real-World (RW)	**Virtual Environment (VE)**
Day 1 Talk-Walk and Run rehearsals w/o OPFOR	Room clearing talk-walk and run rehearsals at field-training site. Building section *similar* to building sections for RW missions	Room clearing talk-walk and run rehearsals at virtual-training site. Building sections *identical* to building sections for RW missions
Day 1 Mission 1 w/ OPFOR	Performance assessment at field-training site	Rehearsal at virtual-training site
Day 1 Mission 2 w/ OPFOR	Performance assessment at field-training site	Rehearsal at virtual-training site
Day 2 Mission 1 w/ OPFOR	Supplemental practice at virtual-training site	Performance assessment at field-training site
Day 2 Mission 2 w/ OPFOR	Supplemental practice at virtual-training site	Performance assessment at field-training site

Note. Two squads per rehearsal condition.

Participants

Participants were 43 soldiers stationed at Fort Benning, Georgia. Soldiers were from three groups, Infantry Officer Basic Course (IOBC) students, a Military Police (MP) National Guard Reserve Unit, and drill sergeants (which also included command and support personnel). Demographic and relevant training experience for the three groups are presented in Appendix B.

The IOBC sample was the youngest (26.9 years) of the three groups followed by the MPs (34.5 years) and the drill sergeants (39.3 years). On the average the three groups spent very little time each week playing virtual reality games (20-60 minutes per week) and had rarely, if ever, trained at the McKenna urban operations training site. Overall, the IOBC sample had a wider experience base in terms of courses completed and simulation exposure.

Soldiers were assigned to four squads for the experiment. Squad members had little, if any, experience working together as a collective element. Rank structure within the squads did not represent the structure of a typical infantry squad. The four squads were randomly assigned to the two rehearsal conditions. One squad was composed of MPs and drill sergeants, one squad consisted entirely of MPs, and two squads were composed of IOBC students. The composite MP/drill sergeant squad and one IOBC squad were assigned to the RW rehearsal condition. The remaining squads were assigned to the VE rehearsal condition. Each rehearsal condition contained one 7 and one 9-man squad. The remaining soldiers served as OPFOR.

Instruments

Biographical Questionnaire. The Biographical Information Questionnaire (Appendix A) was a multiple-choice/short answer paper-and-pencil instrument designed to document the prior military training and experience of each soldier as well as their experience with computers and simulations.

Real World and Virtual Environment Post Training Questionnaires. After completing the mission rehearsal training, soldiers completed one version of this multiple choice/short answer questionnaire (Appendix C or D). The questionnaire consisted of six items that required participants to rate the effectiveness of the training received, rate the adequacy of time allocated for rehearsing, state what they liked most/least about the rehearsal setting, and state how they would modify the rehearsals to make them more effective.

Mission Rehearsal Comparison Questionnaire. After soldiers had the opportunity to execute missions in both settings (virtual environment and real world), they completed the Mission Rehearsal Comparison Questionnaire (Appendix E). The questionnaire consisted of six multiple choice/short answer items on the relative effectiveness of the rehearsal settings, the advantages and disadvantages to conducting mission rehearsals in a virtual environment, and how to incorporate virtual environments in unit training.

Evaluation Checklist. The Evaluation Checklist (Appendix F) was completed after the execution of each mission by two O/Cs. The checklist consisted of 17 measures (only 15 measures were used for assessing performance) of squad and individual performance for clearing a building, e.g., number of rooms not properly cleared, failure to provide supporting fires, failure to maintain proper dispersion at danger areas, and personnel "flagging" of squad members or their weapons in windows or around corners. The O/Cs used the checklist to record the number of times these events were observed.

For each mission that involved a force-on-force encounter with the OPFOR, the O/Cs completed a formal evaluation. Each squad received four sets of ratings from each O/C, two ratings based on real-world mission performance and two ratings based on mission performance in the virtual environment. Later, the O/Cs reviewed replays and data files from each mission to verify their assessments and correct any discrepancies.

Frequency counts were obtained for each task/measure (i.e., the number of instances the squad or squad member did not correctly perform a specific task, number of friendly and OPFOR casualties, and number of fratricides). For all measures except the number of OPFOR casualties, higher frequency counts represented poorer tactical performance. Inspection of the collective tasks indicated that they clearly varied in importance or criticality (see Appendix F for further details). As a result, a scoring and weighting scheme was developed by military subject matter experts to reflect these differences and allow all measures to be combined into a single performance score.

Of the tasks that were identified, certain tasks were recognized as having a more significant effect in determining the final outcome of a mission and in assessing overall unit

performance. Therefore, these tasks were assigned a heavier weight than other tasks. Ultimately, three weight categories were developed.

A weight factor of three (3) was assigned to three measures deemed critical for determining the squad's performance at end state. These were: the squad's manpower strength at end of the mission, the OPFOR threat to the clearing operation - all OPFOR had to be eliminated in order for the squad to successfully complete the mission and, the number of fratricides.

A weight factor of two (2) was given to tasks that, if not correctly performed, could result in casualties and/or compromise mission success. Assessment areas included: the number of rooms not properly cleared; dispersion at danger areas; soldier placement, to include individual location in relation to the rest of his unit, and his ability to provide supporting fires from that location; and the soldier's understanding of his leader's directions and intent.

A weight factor of one (1) was assigned to tasks that dealt more with correct individual performance rather than situations entailing the possibility of producing casualties. These areas included successful urban operation techniques, safety actions, and command and control issues, e.g., Did the soldier needlessly expose himself to possible sniper fire? Were weapon muzzles pointed away from friendly soldiers? Was a succession of command established and how well did the squad react when a leader became a casualty? For descriptive purposes, tasks or measures receiving weights of 3, 2, or 1 were classified as Level III, II, and I tasks, respectively.

For each task, frequency bands were calculated. Depending on the raw frequency count, a specific score was assigned to the task based on the band that the frequency tally fell in. For example, if 10 counts of personnel flagging were observed, the squad would receive a score of 3. This task would then be multiplied by its weight, 1. The final transformed score for this task would be 3. Each task was scored in a similar fashion. These individual weighted scores were then summed to provide a total score. The maximum total weighted score that could be obtained was 135. Table 2 lists each of the collective tasks and behaviors, their corresponding weights and frequency band scores.

Table 2
Importance Ratings and Associated Frequency Band Scores by Task (from Evaluation Checklist)

Task/Behavior	Weight	Frequency Band and Associated Score
1. Number of BLUFOR casualties	3	0 = 5 pts 3 = 1 pt 1 = 4 pts ≥4 = 0 pts 2 = 2 pts
2. Number of OPFOR casualties	3	3 = 5 pts ≤2 = 0 pts
3. Number of BLUFOR fratricides	3	0 = 5 pts ≥1 = 0 pts
4. Number of rooms **not** properly cleared	2	0 = 5 pts ≥1 = 0 pts
5. Soldiers did **not** maintain relative position with each other providing protective cover	2	0 = 5 pts ≥1 = 0 pts
6. Soldiers did **not** maintain dispersion at danger areas (areas with more than one angle of attack)	2	0 = 5 pts ≥1 = 0 pts
7. Soldiers were **not** placed to provide supporting fires for other soldier conducting movement	2	0 = 5 pts ≥1 = 0 pts
8. Soldiers did **not** accurately report OPFOR location	2	0 = 5 pts ≥1 = 0 pts
9. Team member did **not** understand his respective sector of fire and provide adequate support	2	0 = 5 pts 1 = 3 pts ≥2 = 0 pts
10. Personnel "flagging" (exposed in windows or head exposed around corner) for > 5 seconds	1	≤4 = 5 pts 11-13 = 2 pts 5-7 = 4 pts 14-15 = 1 pt 8-10 = 3 pts ≥16 = 0 pts
11. Soldiers "flagged" (extended M16 barrel beyond cover) at corners	1	≤4 = 5 pts 11-13 = 2 pts 5-7 = 4 pts 14-15 = 1 pt 8-10 = 3 pts ≥16 = 0 pts
12. Weapons not held correctly (entering a room muzzles pointed at friendly forces)	1	0 = 5 pts 3 = 2 pts 1 = 4 pts 4 = 1 pt 2 = 3 pts ≥5 = 0 pts
13. Once room was cleared, team did **not** yell, "Clear" to inform the support element	1	0 = 5 pts 3 = 2 pts 1 = 4 pts 4 = 1 pt 2 = 3 pts ≥5 = 0 pts
14. Unit tactics were **not** doctrinally sound	1	0 = 5 pts 1 = 3 pts ≥2 = 0 pts
15. Succession of command **not** established	1	0 = 5 pts 1 = 3 pts ≥2 = 0 pts

Note. 3 = high priority task; 2 = moderate priority task; 1 = low priority task

Mission Scenarios

All scenarios were set in a small European town. The town was, in fact, the McKenna urban operations training site. A virtual representation of the town was created for mission rehearsal and execution at the Virtual Simulation Lab. Military subject matter experts developed two scenarios that required clearing different sections of a two-story building complex (Appendixes G and H). Scenarios assessed squad tactical proficiency across a predetermined set of doctrinally approved tasks. The scenarios were also scripted to last approximately 30 minutes for scheduling purposes and to maintain group focus. The OPFOR consisted of three soldiers from the participating unit. Live OPFOR elements were used in both training settings.

Equipment

Virtual-Training Site

Soldier Visualization Station (SVS). Nine full-immersion SVS systems (helmet mounted display [HMD], weapon, screen) were employed along with four joystick controlled, desktop systems. The full-immersion systems were housed in their own enclosures but linked with each other and the desktops. Technical specifications of the two different versions are shown in Table 3. Squad members could communicate with each other and the squad leader. The squad leader could communicate with the platoon leader, role played by one of the O/Cs. Communication procedures were similar, but not identical to what soldiers would be accustomed to in a real-world environment.

Each squad member operated an SVS, while the platoon leader operated a desktop system. The squad members were located in one building while the platoon leader and battlemaster (simulation system/scenario coordinator) were adjacent to each other in another room, away from the SVS systems. The OPFOR element operated the remaining desktops from another building.

Table 3
Technical Specifications of the Immersive SVS and Desktop SVS Simulation Systems

System Hardware (Immersive and Desktop)	• Pentium III – 450 MHz microprocessor • 128 Mb RAM • Obsidian 200 – 8440 3D Graphics Card • SoundBlaster AWE 64 Gold Audio Card • Removable 4.55 GB SCSI Hard Drive
Movement Control	• Weapon-mounted thumb switch • Desktop SVS – Microsoft joystick control
Motion Capture/ Weapon Tracking	• InterSense Mark2 X-Bar Tracking System • Weapon tracking accurate to within ½ of 1°
Visual Display	• 90° x 60° FOV at center of enclosure (varies with position change) • Rear screen projection resolution 1024 x 768 • Desktop SVS resolution 800 x 600
Enclosures	• Aluminum frame over black sound-dampening fabric. (10 ft. x 10 ft. x 12 ft.)
Software	• Advanced Interactive Systems

After Action Review (AAR) System. A prototype AAR system, located in the OPFOR building, was employed that included two 53-inch screens and two personal computers. The system, which was linked to both the immersive SVS and desktop systems, was able to mark and store key events during the mission, e.g., fratricides, casualties, rounds fired, for subsequent analysis. Marking could be performed automatically or manually by the O/C. These data could not be summarized and displayed on the monitors at this time. However, casualty rates were available for discussion purposes during the AAR. Missions could be replayed from several vantage points. The top-down mode provided a view of the database looking straight down from above. Other viewing modes used included a two dimensional view (top-down) without depth perspective, an entity view (displays what a elected entity sees), and a fly mode used by the O/C to "fly" through the data base using the mouse for control. The O/C selected parts of the mission to replay during the AAR. The O/C also controlled the visual replay of the mission. Replay controls included such actions as pause, stop, record, play, fast forward, fast reverse and rewind. Synchronized audio replay capability was not available for this experiment.

Field-Training Site

Building Instrumentation. The building complex where the missions were executed was fully instrumented. Rooms, stairwells and hallways were monitored with multiple cameras set in fixed locations. Video and audio streams were fed back to the control center that allowed the O/C to track the mission from a distance.

AAR System. AARs were conducted at the control center building. Here, the mission was replayed on multiple large screen monitors. Top-down, two-dimensional animated replays were shown along with ground level video of the squad moving from room to room. The video replay was complemented with synchronized audio playback of verbal comments from the

soldiers during the mission. Specific data concerning the number of casualties and rounds fired were captured but were not able to be summarized and displayed on the video screens. Casualty counts were, however, available for discussion purposes during the AAR. McKenna support personnel controlled the presentation of the audio and video feeds during the AAR. This allowed the O/C to easily structure the focus of the AAR, e.g., what part of the mission to replay, viewing angle.

Simunitions and weapon instrumentation. Soldiers were issued Simunitions, rubber bullets that contain red (OPFOR) or blue (BLUFOR) colored detergent, to help determine if a casualty was the result of enemy or friendly fire. In addition, a laser system was used to specifically determine who inflicted a particular casualty. This system consisted of a laser device mounted on the weapon and a set of sensors that were attached to the soldier's upper body.

Procedure

Real-World Rehearsal Condition

Preparation. Soldiers in the real-world rehearsal condition reported to the McKenna field-training site on Day 1 of the two-day experiment. They were briefed on the objectives of the experiment, and were given the chance to ask any questions concerning their roles in the experiment. They then completed the Biographical Information Questionnaire.

After completing the questionnaire, soldiers were divided into squad and OPFOR elements. Squad and OPFOR members were briefed on the use of Simunitions and the laser monitoring system. All soldiers then zeroed there weapons using the Simunitions. This took approximately 30 to 45 minutes. Soldiers were issued two 20-round magazines (per mission). Squads were issued 3 smoke grenades per squad per mission), and 6 flashbang grenades per squad per mission not including rehearsals).

Next, the squad members received approximately one hour of training, provided by an O/C, that included tactics, techniques, and procedures selected from FM 90-10-1 (Department of the Army, An Infantryman's Guide to Combat in Built-Up Areas - Chapter 5 and Appendix K, 1999). Training was designed to fit individual squad training needs, e. g., instruction on the fundamentals of urban operations or refresher training. The second O/C provided some very basic instruction to the OPFOR members on proper defensive procedures from inside a building (rooms).

The OPFOR received the same guidance from the O/C for all scenarios, virtual and real world. Due to manpower limitations and the need to maintain force ratios of approximately 3:1 (three squad members for every OPFOR soldier), the stairwell was "given" to the squad. That is, the squad was given unhindered access off the stairwells. Moreover, the OPFOR was instructed not to fire on the exercise squad until the third man had deployed on that particular floor of the building. This restriction was established to enhance the squad's survivability at an obvious kill zone.

Instruction for the two groups was provided at separate locations on the McKenna field-training site. Once the instruction was completed the squad members received their operation order. OPFOR members were briefed on their mission objectives in a separate location. Each group was briefed by one of the O/Cs. Each O/C was assigned primary responsibility to either the squad or the OPFOR.

Real-world rehearsal at field-training site. Both the squad and OPFOR were given approximately 30 minutes to plan for the upcoming mission. Once the planning phase was completed, the squad accompanied the O/C to a building site that was similar to the building they would clear during the actual missions. The O/C and the squad then proceeded to "talk and walk" the mission. The O/C accompanied them to the entrance of the building and discussed how they would enter and position themselves as they entered, and the procedures they would use to systematically clear designated rooms or areas in the building. The entire squad accompanied by the O/C then entered the building. The O/C walked through each of the rooms, hallways, and the stairwell with the soldiers and proceeded to point out danger areas and discussed the appropriate tactical response for each of these situations.

The "talk/walk" phase constituted the first rehearsal session and lasted approximately 30 minutes. This was followed by a 30-minute break. The second rehearsal session was the "run" phase. Here, the squad executed the mission at close to full speed, but without an OPFOR. This was followed by on-the-spot corrective feedback from the O/C. The time allotted for this phase was 30 minutes. At the same time the OPFOR was preparing for the mission with the second O/C.

Performance assessment at field-training site. Following the "run" rehearsal, the squad then executed the mission against the OPFOR. The first O/C stayed with the squad at the building site and monitored the mission as it unfolded in the building. The second O/C, who was assigned to the OPFOR, observed the mission from the control center building and served as the platoon leader. After the mission (RW missions ranged from approximately 8 to 20 minutes in duration), both squad and OPFOR members participated in an AAR at the control center building. Prior to the start of the AAR, the O/Cs both completed the Evaluation Checklist. This checklist was used as a general guide for identifying areas of discussion during the AAR. During the AAR, the first O/C reviewed the mission, highlighted key segments of the mission and identified appropriate and inappropriate tactical actions. In addition, the O/C encouraged squad and OPFOR members to elaborate on key events and discuss specific lessons learned.

After the AAR, the squad received their next operation order. The OPFOR, as before, was briefed on the mission at a separate location. The mission required the squad to clear a second section in the same large building complex used for the first mission. The major difference was that the interior floor plan of the second section differed from the first floor plan and presented a slightly different set of challenges to the squad.

No further rehearsals were allowed. Squad and OPFOR elements were allowed 30 minutes for planning which was followed by the actual execution of the mission. After the mission, the same procedure was followed as described earlier. After the AAR, all soldiers completed the Post Training Questionnaire.

Supplemental practice at virtual-training site. On Day 2, soldiers reported to the Virtual Simulation Lab. The purpose for having soldiers in the real-world rehearsal condition come to the lab was to allow them to execute the same missions that they performed in a real-world setting (on Day 1) in a virtual environment. This would provide them an opportunity to compare the strengths and weaknesses of each environment for conducting mission rehearsals.

Soldiers first received approximately 90 minutes of familiarization training on the SVS systems. They used this time to practice moving inside and outside of buildings using the weapon mounted thumb switch, weapon firing, and generally familiarizing themselves with the various computer generated entities including friendly and enemy soldiers, vehicles, aircraft, and furniture. In addition, the soldiers conducted a practice scenario that emphasized moving as a group in and around a building similar to the one they rehearsed in the day before. Prior experience had shown that soldiers needed additional time to adapt to the constraints of the SVS system such as moving tactically, in close contact with others, inside rooms and around corners, sticking in walls, and learning how to back out of walls. The OPFOR was also given time to become familiarized with the desktop system. This system was easier to use and did not take nearly as long for soldiers to master.

Following the familiarization training, the squad received their operation order for the first mission. The OPFOR was briefed separately. Both groups were given 30 minutes for planning. No additional rehearsals were allowed. The squad then executed the mission (VE missions ranged from approximately 10 to 21 minutes). The building section for Mission 1, as well for Mission 2, were virtual representations of the same building sections that the squad had cleared during Day 1 at the McKenna field-training site. Both O/Cs observed the mission on desktop systems in the same room occupied by the battlemaster. This was followed by an AAR. During the transition period prior to the AAR, the O/Cs each completed the Evaluation Checklist.

After the AAR, the squad received their next operation order and the same procedure was followed as described earlier. After the second AAR, soldiers then completed the Mission Rehearsal Comparison Questionnaire.

Virtual Environment Rehearsal Condition

Preparation. Soldiers in the virtual environment rehearsal condition arrived at the Virtual Simulation Lab on Day 1. They were briefed on the objectives of the experiment and also given the opportunity to ask any questions concerning their roles in the experiment. All soldiers then completed the Biographical Information Questionnaire. Soldiers were then assigned to either the squad or OPFOR element. Both groups received the same SVS system familiarization training as did the real-world rehearsal condition soldiers on Day 2.

Following the familiarization training, squad members received approximately one hour of training on urban operation tactics, techniques, and procedures from one of the O/Cs. The second O/C provided some very basic instruction to the OPFOR members on proper defensive procedures from inside a building (rooms). Instruction for the two groups was provided at

separate locations at the Virtual Simulation Lab. Squad members then conducted a practice scenario (15 minutes) in the simulators to fine-tune their collective movement skills. This practice scenario was conducted in a virtual building similar to the one they would rehearse in later.

Virtual-environment rehearsal at virtual-training site. The squad then received their operation order and given approximately 30 minutes for planning. The OPFOR was briefed separately. Squad members then rehearsed the mission twice in the simulators without an OPFOR (talk-walk and run) with both O/Cs observing from desktop monitors in the battlemaster room. This took approximately 45 minutes (30 minutes for the talk-walk, and 15 minutes for the run rehearsals) . These rehearsals were conducted in a virtual representation of the same section of building that they would clear the next day at McKenna. Corrective feedback was provided by the O/Cs following each rehearsal. Unlike the talk-walk and run rehearsals conducted in the real world, the O/C could not walk with the soldiers in the various rooms, hallways, or stairwell to physically point out danger areas, and demonstrate correct tactical movements. The O/C could, however, talk, demonstrate, etc. once all soldiers came out of their SVS systems, but this was conducted in an open area without direct physical access to the building.

Once this rehearsal phase was completed, the squad then executed the same mission against the OPFOR element. After the mission, the O/Cs completed the Evaluation Checklist and then conducted the AAR. The same procedure was repeated a second time. For Mission 2, the rehearsal was conducted first without (talk-walk and run) and then with OPFOR in a virtual representation of the same building section (different from the section used in Mission 1) they would clear the following day.

Following the mission, the O/Cs completed the Evaluation Checklist and conducted the AAR. The soldiers then completed the Post Training Questionnaire. This completed the first day of testing.

Performance assessment at field-training site. On Day 2, soldiers reported to the McKenna urban operations site. Preparation was the same as for the RW rehearsal group. Soldiers were instructed in the use of Simunitions and the laser weapon monitoring system. After zeroing their weapons, soldiers received their first operation order. The OPFOR was briefed separately. As before, the squad and OPFOR were given 30 minutes for planning. The squad then executed the mission, with the two O/Cs monitoring the events at the mission site and the control center. After the mission, the soldiers proceeded to the control center for the AAR while the O/Cs completed the Evaluation Checklist.

The procedure was repeated one more time starting with receipt of the second operation order. After the final AAR was conducted, soldiers then completed the Mission Rehearsal Comparison Questionnaire.

Results

Since the focus was on squad performance, sample size was reduced to 4 (two squads per rehearsal condition). As a result, only descriptive statistics (i.e., means, standard deviations, frequencies) are presented since standard inferential statistics would not be appropriate with such a small sample. For clarity purposes, the performance data is presented by setting (field-training site versus virtual-training site).

Field-Training Site Performance

Figures 1 and 2 depict the transformed field-training site performance scores for each rehearsal group. Figure 1 shows that overall performance improved from Mission 1 to Mission 2 for the VE rehearsal group, increasing from 84 to 92.

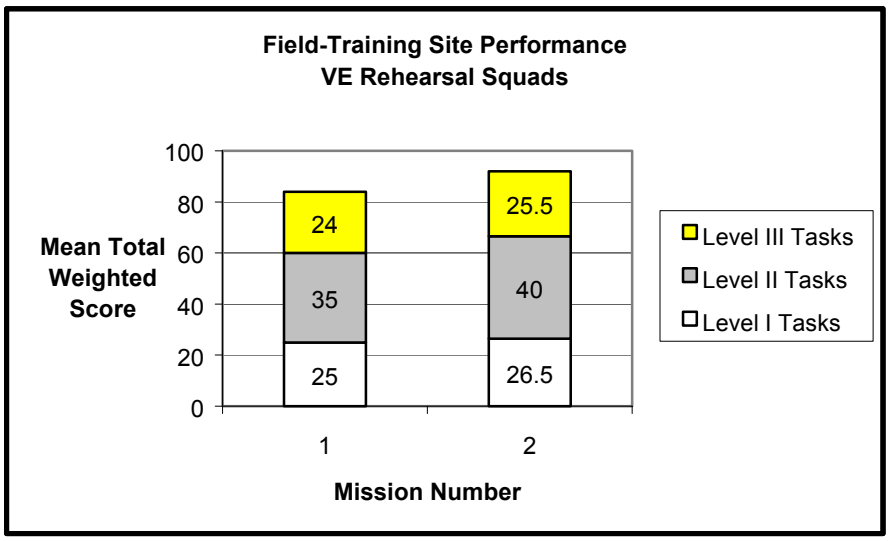

Figure 1. Mean performance scores by task level for VE rehearsal squads at the field-training site.

In contrast, the RW rehearsal group's performance showed little change over missions, 90.5 to 91 for Missions 1 and 2 respectively (see Figure 2).

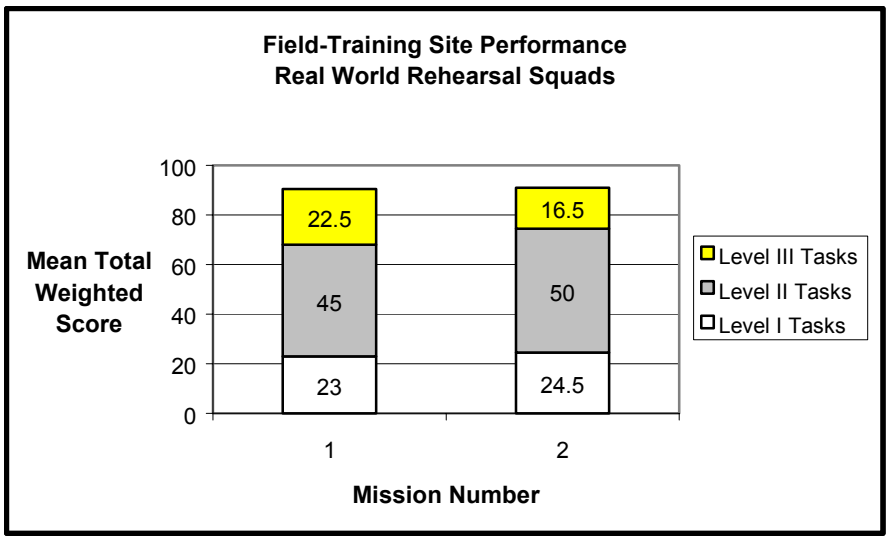

Figure 2. Mean performance scores by task level for RW rehearsal squads at the field-training site

Comparing both groups' performance on their last mission showed no differences (VE rehearsal group = 92 versus RW rehearsal group = 91).

The VE rehearsal group's performance on Level III tasks was better than that of the RW rehearsal group, particularly during Mission 2. The RW rehearsal group performed noticeably better on the Level II tasks. For Level I tasks, the VE rehearsal group's performance was slightly better than that of the RW rehearsal group.

In terms of within group change over missions, the VE rehearsal group showed improvement across all task levels. However the changes observed for Level III and Level I tasks were very slight. For the RW rehearsal group, improvement was most apparent for Level II tasks. Performance showed only slight improvement for Level I tasks. Performance decreased over missions for Level III tasks.

To determine which tasks were most impacted by the rehearsal manipulation, individual tasks within each task level were analyzed. The results are discussed in the following sections.

Group performance on individual level III tasks. Individual task analysis focused on the raw data frequency counts. Figure 3 shows the mean number of friendly squad casualties suffered by each group by mission. Squad casualty rates were generally high (50 percent or more). Mean casualty rates dropped slightly for the VE rehearsal group across missions (6 to 4.5) and increased slightly for the RW rehearsal group for the same missions (5 to 6.0).

Fratricide incidents were seldom, if ever, observed during the execution of the missions. Only one fratricide was observed for the RW rehearsal group. This occurred during the second mission from weapons fire (M16).

With regard to OPFOR casualties, casualty rates were essentially the same for each group. There was no change in the number of OPFOR casualties inflicted from mission 1 to Mission 2 (see Appendix I, Table I-1 for individual incident rates and point totals for all Level III tasks).

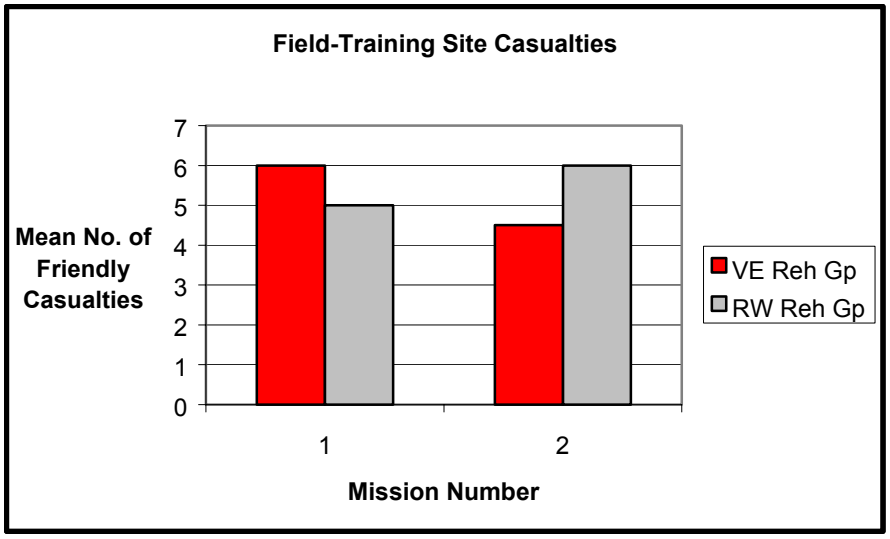

Figure 3. Mean number of friendly squad casualties by rehearsal group at the field-training site.

Group performance on individual level II tasks. Figure 4 shows the frequency of Level II task incidents observed over the two missions. As can be seen from Figure 4, more Level II incidents were observed, overall, for the VE rehearsal group (17) than the RW rehearsal group (11) over missions. Incidents for this group increased from Mission 1 to Mission 2. In contrast, Level II incidents decreased by approximately 50 percent across missions for the RW rehearsal group.

Further analysis showed that three tasks accounted for most of the incidents that were observed (task 4 - *rooms not properly cleared*); task 7 - *failure to place soldiers to provide supporting fires*; and task 8 - *failure to accurately report OPFOR location*). The rehearsal groups did not differ in the total number of room clearing incidents observed. Interestingly, all incidents of improper room clearing were committed on the first mission for the RW rehearsal group. In contrast, the incident rate stayed about the same for the VE rehearsal group from Mission 1 to Mission 2.

For task 7, failure to provide supporting fires, all incidents observed (4) were committed by the VE rehearsal group. Performance for this group degraded from Mission 1 to Mission 2. For task 8, slightly more incidents of not reporting the OPFOR location were noted for the VE rehearsal group (4 versus 2 for the RW rehearsal group). Performance for both groups degraded slightly over missions. The overall incident rate, however, for both tasks 7 and 8 was low (see Appendix I, Table I-2 for individual incident rates and point totals for all Level II tasks).

Figure 4. Total number of level II task tactical incidents by rehearsal group at the field-training site.

Group performance on individual level I tasks. Figure 5 shows the frequency of Level I task incidents by rehearsal group across missions. More Level I incidents were observed for the RW rehearsal group than the VE rehearsal group. Performance improved from the first to the second mission for both groups. The majority of incidents observed centered around three tasks. Task 10 - *personnel "flagging" (body exposed in windows or head exposed around corners)* had the most incidents. A total of 35 flagging incidents were observed. The RW rehearsal group flagged 21 times during the missions compared to 14 for the VE rehearsal group. Flagging incidents decreased over missions for both groups.

For the remaining two tasks, task 11, *weapon "flagging" (extending M16 barrel beyond cover*) and task 15, *succession of command not established,* the number of incidents observed was 11 and 12 respectively. For weapon flagging, there was no difference between the two groups, in terms of total incidents observed. With regard to not establishing succession of command, the RW rehearsal was cited more often (9 incidents) than the VE rehearsal group (3 incidents). For both groups, performance changes from Mission 1 to Mission 2 were negligible for these two tasks (see Appendix I, Table I-3 for individual incident rates and point totals for all Level I tasks).

Figure 5. Total number of level I task tactical incidents by rehearsal group at the field-training site.

Virtual-Training Site Performance

The weighted group performance scores for the two virtual environment missions were also computed to address performance differences between rehearsal environments and to assess possible simulation system shortcomings (see Figures 6 and 7). Figure 6 shows that overall performance improved from Mission 1 to Mission 2 for the VE rehearsal group, increasing from 70.5 to 82. In contrast, the RW rehearsal group's performance showed relatively little change over missions, 87.5 to 91.5 for Missions 1 and 2 respectively (see Figure 7). Overall, the RW rehearsal group's performance at the virtual-training site was better than that of the VE rehearsal group for each mission.

Further inspection of Figures 6 and 7 shows that the RW rehearsal group's performance was better on Level III as well as Level II tasks. VE rehearsal group scores for Level I tasks during Mission 2 were better than those obtained for the RW rehearsal group.

The VE rehearsal group showed improvement over missions for both Level II and Level I tasks. Improvement on Level II tasks was most apparent. Level III task performance was relatively poor and decreased slightly over missions. For the RW rehearsal group, performance improved for Level II tasks but remained essentially unchanged for both Level III and Level I tasks.

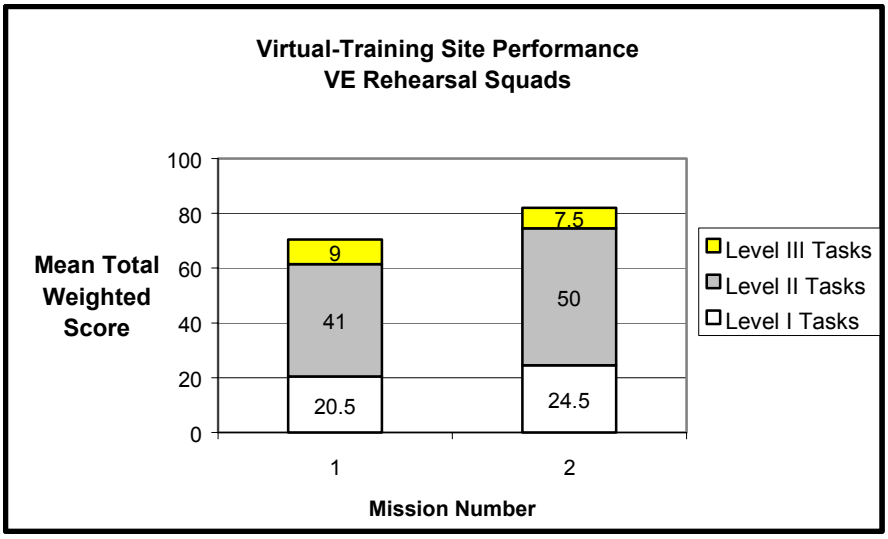

Figure 6. Mean performance scores by task level for VE rehearsal squads at the virtual-training site.

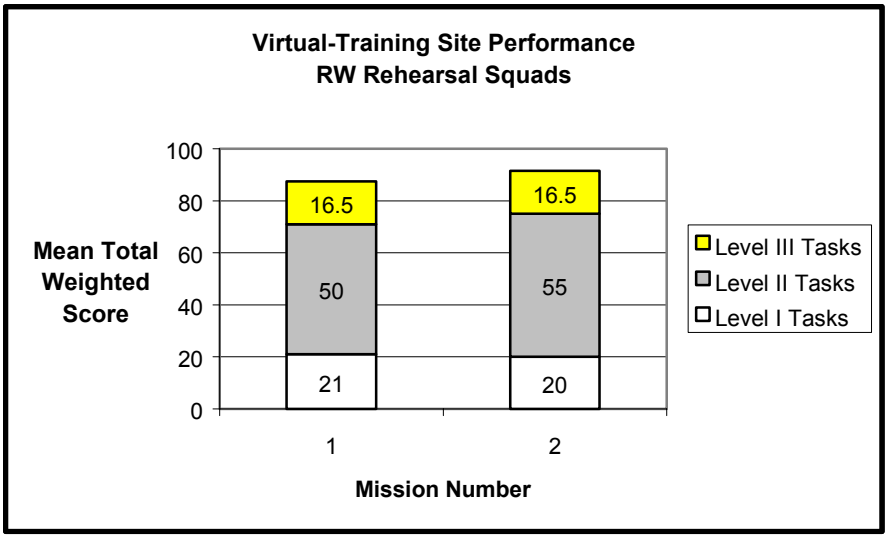

Figure 7. Mean performance scores by task level for RW rehearsal squads at the virtual-training site.

To determine which tasks were most impacted by the rehearsal manipulation, individual tasks within each task level were analyzed. The results are discussed in the following sections.

Group performance on individual level III tasks. Individual task analysis once again focused on the raw data frequency counts. Figure 8 shows the mean number of friendly squad casualties suffered by each group by mission. Virtual-training site casualty rates remained high (50 percent or higher) across missions for both groups [see Figure 8]. Overall, the casualty rates differed slightly as a function of rehearsal condition (RW rehearsal group = 5.0 and VE rehearsal group = 5.7)

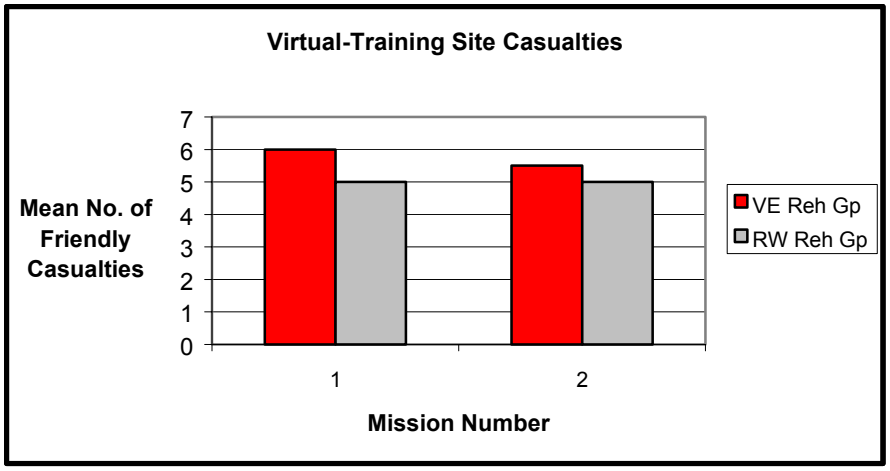

Figure 8. Mean number of friendly squad casualties by rehearsal group at the virtual-training site.

All but one of the 16 (94 percent) observed fratricides occurred in the virtual environment. As can be seen from Figure 9, the fratricide rate increased across missions performed in the virtual environment by the VE rehearsal group. The increased rate of fratricides can most likely be attributed to the emphasis placed on the use of grenades for Mission 2 for one of the squads and inadequate training in the use of the grenade system. (Twelve of the 15 fratricides observed in the virtual environment were the result of grenades. All VE rehearsal group fratricides were from grenades.)

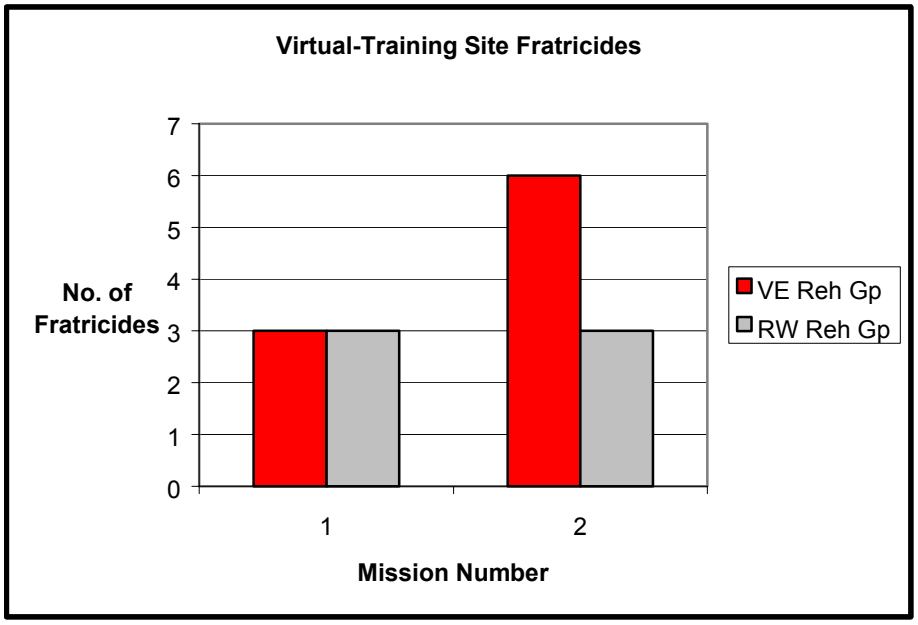

Figure 9. Total number of fratricides by rehearsal group at the virtual-training site.

The physical act of throwing a grenade in a virtual environment was very different (awkward and unrealistic) from throwing a grenade in the real world. Overall, it was clear that more practice should have been allocated for soldiers to familiarize themselves with how to effectively "throw" grenades in the virtual environment (see Appendix I, Table I-4 for individual incident rates and point totals for all Level III tasks).

As was the case at the field-training site, OPFOR casualty rates were essentially the same for each group. There was no change in the number of OPFOR casualties inflicted from Mission 1 to Mission 2.

Group performance on individual level II tasks. Approximately 4 times as many Level II task tactical incidents were observed for the VE rehearsal group compared to the RW rehearsal group. Incidents decreased over missions for the VE rehearsal group but remained stable and low for the RW rehearsal group (see Figure 10).

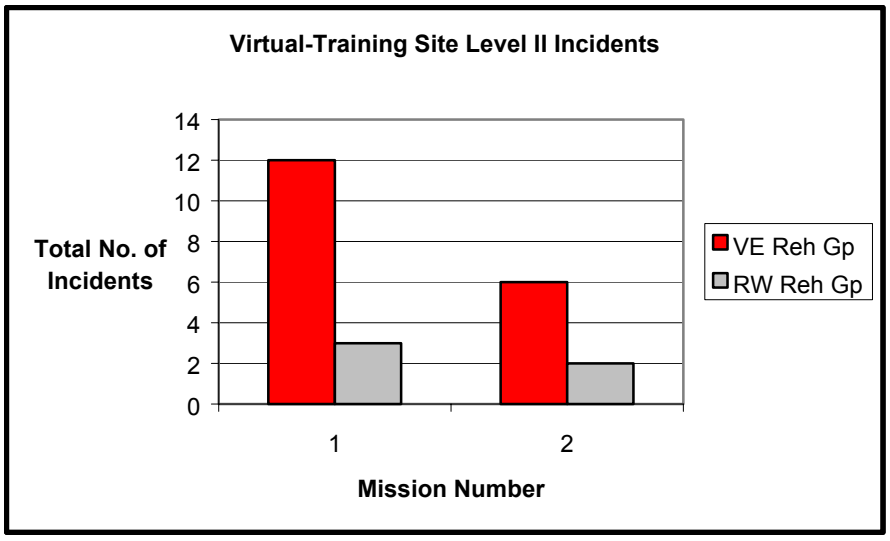

Figure 10. Total number of level II task tactical incidents by rehearsal group at the virtual-training site.

Further analysis also showed that three tasks accounted for the majority of errors that were observed, task 4 *(rooms not properly cleared)*; task 5 *(failure to maintain proper position for providing protective cover)*; and task 7 *(failure to place soldiers to provide supporting fires for other soldiers conducting movement)*.

For task 4, all room clearing incidents that were observed (7) came from the VE rehearsal group. For task 5, all but one incident of soldiers failing to maintain relative proper position with each other to provide protective cover was observed for the VE rehearsal group (6 versus 1). A similar, but slight trend was observed for task 7. All incidents (3) of improperly placing soldiers to provide supporting fires for soldiers conducting movement came from the VE rehearsal group (see Appendix I, Table I-5 for individual incident rates and point totals for all Level II tasks).

Group performance on individual level I tasks. Analysis of the incident rates for the virtual environment missions showed that more Level I task incidents were observed for the RW rehearsal group than for the VE rehearsal group. The performance of the VE rehearsal group showed some improvement over time. However, the RW rehearsal group's performance got worse over the two missions (see Figure 11).

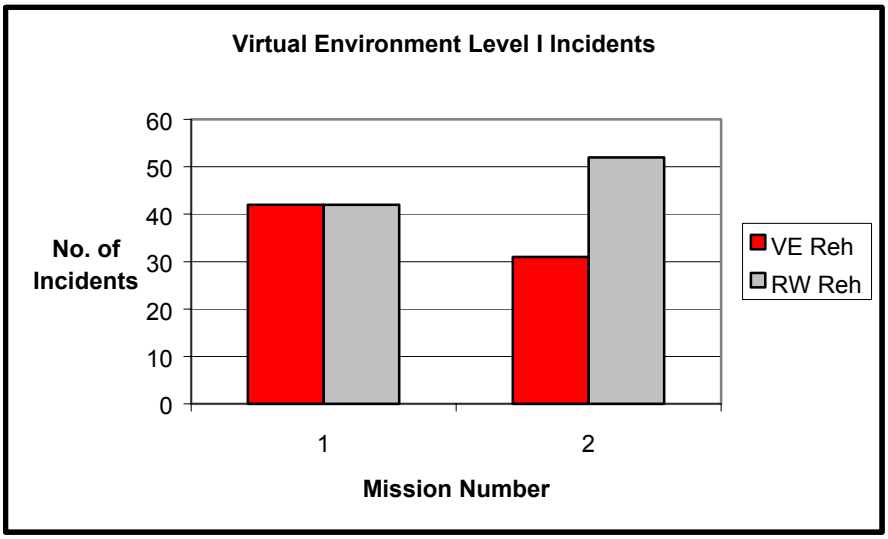

Figure 11. Total number of level I task tactical incidents by rehearsal group at the virtual-training site.

Further analysis showed that Task 10*, personnel " flagging" (body exposed in windows or head exposed around corners)* accounted for the majority of Level I task incidents that were observed. Overall, 142 flagging incidents were noted (60 incidents for the VE rehearsal group and 82 incidents for the RW rehearsal group). Incident rate across all tasks were more frequent in the RW rehearsal condition (94) than in the VE rehearsal condition (73).

Two tasks, task 11*, weapon "flagging" (extending M16 barrel beyond cover)* and task 15 *(succession of command not established)* had the next most frequently observed incident rates (9 and 8 incidents respectively). For weapon flagging, the incident rate was roughly the same for each rehearsal group (5 for the VE rehearsal group and 4 for the RW rehearsal group). For both groups, all incidents were observed during Mission 1. For task 15, the overall incident rate for failing to establish succession of command was identical for both rehearsal conditions (4). However, all VE rehearsal group incidents occurred during mission 1 (see Appendix I, Table I-6 for individual incident rates and point totals for all Level I tasks).

Comparison of Field Versus Virtual-Training Site Performance

Breaking down performance by task level and training site did reveal some interesting patterns. For Level III task performance, friendly casualties were high (50 percent or higher) for both groups across both settings. Differences in the total number of OPFOR casualties inflicted across rehearsal condition and setting were negligible. Of the sixteen missions that were

conducted (4 squads X 2 virtual-training site missions X 2 field-training site missions), the squads suffered one hundred percent casualties on seven of the missions.

The one Level III task performance measure that showed any significant variability was fratricides. Fratricides decreased noticeably for the VE rehearsal group as they moved from the virtual-training site (9) to the field-training site (0). As mentioned earlier, this improvement was due primarily to SVS system constraints. When the RW rehearsal group moved from the field-training site to the virtual-training site, fratricides increased noticeably (1 fratricide versus 6 fratricides for field and virtual-training sites, respectively). [See Appendix I, Tables I-1 and I-4). The rather large point discrepancy (9.5 points) between the two rehearsal groups for mission 2 observed at the field-training site, can be attributed primarily to the one fratricide committed by the real-world rehearsal group.

For Level II tasks, analysis of the total number of incidents at both the field and virtual-training sites revealed that over twice as many incidents were recorded for the VE rehearsal group (35) than for the RW rehearsal group (16). Tasks 4, 5, 7 and 8 accounted for most of the incidents that were observed. Interestingly, Figures 1 and 2 show that Level II performance improved for both groups at the field-training site, but the incident rates did not support this pattern for the VE rehearsal group. In this instance, incident rates increased over missions for the VE rehearsal group but decreased for the RW rehearsal group (see Figure 4). This is most likely a scoring artifact. For 5 of the six Level II tasks, the occurrence of one incident results in the squad receiving a score of zero. Additional incidents, therefore, will not be reflected in the weighted score. So, it is possible for a squad to have an increasing incident rate over missions, yet their weighted scores continue to show improvement. This could happen, for example, if the incidents are concentrated in a few tasks. This would also explain why large differences in incident frequencies between groups do not necessarily correspond to large differences in weighted scores.

Level I tasks clearly had the most recorded incidents. For the six Level I tasks, 236 negative incidents were observed across both environments. Task 10*, personnel "flagging" (body exposed in windows or head exposed around corners)* accounted for 75 percent (177 incidents) of the total incidents observed. The majority of flagging incidents occurred at the virtual-training site (142 or 80 percent).

Soldier Assessment of Rehearsal Training

After the rehearsal training, soldiers completed either the Real World or Virtual Environment Post Training Questionnaire. Open-ended questions were content analyzed and summarized in Tables 4-6. The most common responses are listed first.

What soldiers liked most about rehearsing in a real-world or virtual-environment setting. Table 4 lists the most positive aspects noted for rehearsing in each setting. The majority of soldiers in the RW rehearsal condition felt that these rehearsals were comparable to performing a similar mission in the real world, and provided them with a better understanding of the essential tasks and skills that were required to complete the mission.

Soldiers remarked that the real-world training environment was "hands-on" and allowed them to experience the environment as they would during a real-world mission. The most frequently cited characteristics that contributed to this "hands-on" training environment included the ability to climb stairs, lean against walls, throw grenades, use hand signals, peek around corners, use peripheral vision, and move obstacles. All of these tasks or behaviors were viewed as essential components that must be addressed in training soldiers how to effectively clear buildings. Other characteristics that soldiers mentioned that increased the realism of this type of rehearsal training included climate and battle gear requirements.

Additional comments indicated that the soldiers clearly enjoyed using simunitions during the execution of the missions. Soldiers felt that these paint filled bullets created the perception of live fire battle, and motivated them to take cover and to move more tactically. Soldiers added that getting shot by a simunition round provided them with instant feedback that they had made a mistake. One soldier commented that training in the real world with simunitions helped in "…*eliminating anxiety about what would happen when rounds fly."* Soldiers also noted that the training allowed them to identify team weaknesses and taught them to respond more quickly and efficiently.

Table 4
What Soldiers Liked Most About Rehearsing in Real-World and Virtual-Environment Settings

Real World	• Provided a realistic training setting • Improved understanding of the mission and related tasks • Enhanced the learning process • Addressed team weaknesses quickly • Provided effective urban operations training • Made mistakes more visible
Virtual Environment	• Provided a comfortable environment • Was similar to real-world training • Improved preparation for urban operations • Provided a safe training environment • Aided mission planning • Introduced mission related tactics effectively • Increased squad integrity or completeness • Provided entertaining, attention grabbing training

The general theme concerning virtual mission rehearsal training was that this environment provided soldiers with a comfortable training setting. The training was not physically taxing, they were not required to wear full battle gear, and the climate was ideal (cool with low humidity). Soldiers indicated that the absence of these physical distractions allowed them to be able to conduct more rehearsals and train for longer periods of time.

A second common theme was safety. Soldiers believed that they were safe from injury while training in the virtual environment.

What soldiers liked least about rehearsing in a real-world or virtual-environment setting. Aspects of rehearsing in a real-world or virtual-environment setting that soldiers liked the least are summarized in Table 5. For soldiers in the RW rehearsal condition, the primary training comments focused on the slow pace of training and limited rehearsal opportunities (two). A few soldiers mentioned that they would have liked more basic urban operation skill training (to include clearing buildings) at the unit level, prior to rehearsing at the McKenna site.

The remaining comments focused on the weather conditions at the McKenna site. Soldiers disliked the heat that they were exposed to during the training. This research was conducted in mid July where temperatures hovered in the mid 90s with very high humidity. The discomfort was magnified by the additional protective gear (body vests, face shields) the soldiers wore to protect them from the simunition rounds. The extreme heat was one reason for the slow training tempo. The impact that climatic conditions may have had on training was not discussed.

Table 5
What Soldiers Liked Least About Rehearsing in Real-World and Virtual Environment Settings

Real World	• The heat • Not enough time for many rehearsals • The slow pace
Virtual Environment	• Difficult to maneuver through the environment • Less realistic than the real-world training • Time required to learn to use the virtual system • The menu was difficult to use • Getting stuck in walls affects the mission • Grenades are difficult to use • Field of view is limited • The microphone was too loud

Soldiers in the VE rehearsal condition commented on several aspects of the environment that they felt had negatively affected their mission performance. The major theme focused on maneuverability. Soldiers indicated that they were not able to move as fluidly or as naturally (using the weapon mounted thumb switch) as they would have in the real-world environment. They felt that the constraints on mobility increased the difficulty for them to execute the movements necessary to complete mission related tasks.

Soldiers also felt that the "sticking" aspect of this virtual system further affected the fluidity of motion. If the soldier got too close to the sides of a building, parts of his body would get stuck in the wall. Sometimes the soldier's limbs or weapon would protrude through the wall into the enemy's view. When the sticking resulted in exposed limbs or weapons, the element of surprise was lost, and soldiers shot at the limbs/weapons, resulting in casualties early in the mission.

Soldiers mentioned several other aspects of the system that affected its efficiency as a training tool. These included: difficulty in performing simple tasks (i.e., throwing grenades),

difficulty using the menu to execute various actions, and the narrow field of view (FOV). Soldiers felt that these deficiencies decreased the realism of the training.

Suggestions for improving the effectiveness of mission rehearsals. Soldiers were asked what they would do to improve the effectiveness of mission rehearsals. Comments are summarized in Table 6. The majority of the soldiers in the RW rehearsal condition indicated that they would not modify anything.

Soldiers with specific comments suggested that trainers alternate leadership positions between missions to increase the squad members' understanding of how each position affects the mission. They also recommended increasing the number of members in each squad (from 7 to 9), increasing the training time and number of rehearsals, and conducting additional basic urban operation skill training prior to rehearsal.

Table 6
Suggestions for Improving Mission Rehearsal Training in Real-World and Virtual-Environment Settings

Real-World	• Alternate squad member leadership positions • Improve unit level urban operation skills prior to mission rehearsal • Provide more time for additional training and rehearsal • Increase the size of each squad (9-man squad) • Use more instructors
Virtual Environment	• Remedy virtual figures sticking in walls • Separate each control button from the menu • Improve mobility of motion through the environment • Add additional urban operation skills training • Enlarge the field of view (FOV) • Create a virtual view based on head movement, not a toggle • Add maps and target references on the virtual screen • Improve grenade usability

Soldiers in the VE rehearsal condition provided a number of suggestions for improving the rehearsal process. The biggest issue was correcting the "sticking" problem in the SVS system. Soldiers felt that the training effectiveness of the SVS system could be greatly enhanced if this problem was resolved. They viewed the current unstick option on the screen menu as inadequate.

Soldiers recommended the development of an "unstick" button that is separate from the weapons selection menu so it could be used more quickly and easily. Currently, to unstick you must select (using the thumb switch on the weapon) the first item among a list of weapon choices appearing on the screen. Because it is the first item, it is sometimes easy to overlook causing the user to have to scroll back to the beginning. This provides time for the enemy to locate and engage the soldiers. This is compounded if the soldier's virtual limbs or weapon are sticking through the wall revealing the soldier's position while he is attempting to free himself.

Soldiers preferred a larger FOV in the virtual environment, suggesting that the current screen be enlarged to allow for 360 degree viewing of the mission environment. At the very least the soldiers recommended a screen that would allow the user to look up, down, and side to side. For changing views, soldiers indicated that instead of toggle manipulation, the view should be based on the head movements of the user.

A number of soldiers found the virtual grenades difficult to use. If the grenade toss (using the weapon) was not timed correctly according to a calibration figure in the center of the screen, the grenade would drop at the soldier's feet and explode, producing a fratricide. Clearly, a more realistic, user-friendly means of throwing grenades is needed.

Other suggestions for improving the effectiveness of virtual environment mission rehearsals focused on enhanced maneuverability, a revised menu consisting of separate control buttons for each choice of weapons, a target reference for shooting, and a reference map showing the position and the direction of travel of all squad members during the exercise. This last feature is not available in the real world. In addition, soldiers recommended including more realistic battlefield sounds such as footsteps, weapons being loaded and fired, people talking in whispered English and other foreign languages depending on the enemy's origin, and grenades being activated and dropped. Soldiers also felt they needed additional training time on the virtual system.

Soldier Comparison of Real-World Versus Virtual-Environment Mission Rehearsals

Effectiveness of rehearsal setting. At the end of the experiment, soldiers completed the Mission Rehearsal Comparison Questionnaire. This questionnaire was used to give soldiers a chance to compare the effectiveness of each environment for conducting rehearsals. Table 7 summarizes soldiers' responses to the question *"Based on your experiences this week, could virtual environments be used to conduct effective mission rehearsals?"*

Table 7
Percent Response to Question "Could Virtual Environments be Used to Conduct Effective Mission Rehearsals?"

	VE Rehearsal Squads	RW Rehearsal Squads
Yes	94	44
No	6	19
Yes and No	0	31
No answer	0	6

Note. n = 16 for each condition.

Ninety-four percent of the soldiers in the VE rehearsal condition felt that virtual environments could be effectively used to conduct mission rehearsals. In contrast, only 44 % of the soldiers in the RW rehearsal condition felt the same way. Half of the RW rehearsal soldiers expressed either mixed feelings (yes and no) toward virtual environments or felt these VE systems were not an effective means for conducting mission rehearsals.

Soldiers were asked to specifically compare the effectiveness of virtual environments versus the real world for conducting mission rehearsals. Table 8 shows the percentage breakdown by rehearsal condition. As shown, 50 % of the soldiers in the VE rehearsal condition felt that virtual environments were as effective as the real world for conducting mission rehearsals. Forty-four percent said that virtual environments were less effective than the real world. In contrast, all soldiers in the RW rehearsal condition felt that the virtual environment was less effective than rehearsing in a real-world setting.

Table 8
Percent Response to Question "Compare the Effectiveness of Virtual Environments Versus the Real World for Conducting Mission Rehearsals"

	VE Mission Rehearsal Condition	RW Mission Rehearsal Condition
VE less effective than RW	44	100
VE just as effective as RW	50	0
VE more effective than RW	6	0

Note. n = 16 for each condition.

Soldiers who felt that virtual environments were less effective than real-world settings for conducting mission rehearsals emphasized the realistic "hands-on" nature of real-world training Movement in the virtual environment via the thumb switch, getting stuck in walls, and menu layout at various times frustrated soldiers and negatively affected the realism and overall training value of the virtual environment rehearsal process. Some soldiers felt that virtual environment rehearsal could be as effective as a real-world rehearsal, but not with the current level of technology.

Soldiers who felt virtual environments were as effective as real-world rehearsals mentioned the safety aspects of this type of training, the optimal training conditions (climate, not physically strenuous), and cost effectiveness (can quickly and cheaply construct mock-ups of different terrain and buildings, and the ability to conduct more repetitions per unit of time).

Advantages of rehearsing in a virtual environment. Soldiers were asked to list the major advantages to rehearsing in a virtual environment. Their comments are summarized in Table 9. Soldiers felt that virtual environment systems could provide an effective method for familiarizing units (e.g., squads) with the mission environment and for teaching (basic) urban operation principles and skills. These systems could also be used for refining tactics, mission planning, and building unit cohesion and teamwork. Virtual rehearsal training was viewed as more time and cost effective for a number of different reasons detailed in Table 9.

Table 9
Advantages to Conducting Mission Rehearsals in a Virtual Environment

• Provides a realistic preview of mission environment
• Provides a comfortable training environment
• Provides a safe training environment
• Is effective use of training time and cost
• Requires less physical demands, therefore allowing for more rehearsals
• Allows leaders to analyze tactical issues/scenarios prior to mission execution
• Can rehearse a mission many times if necessary
• Is available when urban training sites are reserved
• Builds unit cohesion and teamwork
• Does not waste ammunition
• Is good for teaching urban operation principles and skills
• Allows for planning and rehearsing missions quickly

Disadvantages to rehearsing in a virtual environment. Soldiers were also asked to list the disadvantages to rehearsing in a virtual environment setting. Table 10 summarizes their comments.

Table 10
Disadvantages to Conducting Mission Rehearsals in a Virtual Environment

• Restricts movement
• Provides environment that is too comfortable
• Lacks realism
• Is difficult to use the controls and menu
• Has a narrow FOV
• Is less hands-on than the real-world training
• Contains too many glitches in the technology (e.g., sticking)
• Is too much like video game

Lack of mobility represented a major disadvantage according to many of the soldiers. The weapon-mounted thumb switch did not allow soldiers to move fluidly. This thumb switch or toggle approach to movement did not allow for effective rehearsal of such key urban operation skills as moving through doors, moving through a building as a squad, and peeking around corners, throwing grenades, or stacking.

As noted previously, soldiers clearly liked the comfortable environmental conditions associated with virtual training. However, they felt that they still needed the more physical real-world training to fully appreciate the conditions they would face in a real-world urban operation setting such as heat, rain, cold, fatigue, stress, carrying heavy equipment and weapon recoil.

Soldiers felt that the controls were difficult to master to the level necessary to effectively perform the missions in the virtual environment. Calibrating grenades and choosing weapons

caused some frustration during mission rehearsal. Soldiers commented that it took too much time to scroll through the menu options and they often missed the weapon they had intended to select and had to start from the beginning of the menu. This delay in action often provided the enemy with needed time to detect and engage the soldier, which resulted in additional casualties for the squad.

Soldiers indicated that the limited FOV in the virtual environment did not permit them to use their peripheral vision. In order to see peripherally, they had to move their own avatar (simulated soldier image) by manipulating the toggle which was awkward and imprecise. Soldiers stated that peripheral vision is a sense that is needed for conducting critical operational tasks (precision movements through doors and rooms).

Another disadvantage mentioned by soldiers was the lack of physical interaction with the virtual environment. Specific examples cited included the inability to lean against walls, feel the presence of team members who are in close proximity, and use hand signals and eye contact for communication. Soldiers also felt that because they could not feel or hear rounds flying through the air that they were missing valuable environmental cues to take protective cover.

Incorporating virtual environments in unit training. Soldiers thought virtual environments could be effectively used at the unit level for familiarizing unit members with the mission environment prior to arrival at the real-world site (see Table 11). This included familiarization of the layout of the buildings, rooms and surrounding areas (e.g., possible target locations, enemy movement routes, observation points). Virtual environments could also be incorporated in unit training for mission planning and for refining tactics.

Soldiers mentioned that virtual environments could provide the unit with alternate, cost effective training that could be exploited when time/resource constraints limit the availability of real-world training sites. For example, fundamental building clearing procedures, tactics, and leadership training could be conducted before transitioning to the to the real-world site. The actual urban training site could then be more efficiently used to focus on the physical execution of the mission. In addition, soldiers indicated that the virtual environments could be used to conduct refresher training. Virtual environment training was also viewed as an effective means to teach leaders and squad members how to work together, develop unit standing operating procedures (SOP), and improve decision-making skills.

Table 11
Soldier Responses to Question "How Would You Incorporate Virtual Environments in Your Unit's Training?"

• As pre-training before training in the real world
• To familiarize unit members with environment
• For mission planning
• For leadership development
• To introduce urban operation skills before training
• For teaching mission tactics
• For building teamwork within a squad
• To explore different mission environments and scenarios
• To retain proficiency in urban operation skills
• When urban operation training sites are not available and time/resources are limited
• For alternating training environments with different training objectives
• To improve decision making-skills
• To develop unit SOP
• For rehearsing non-urban operation mission scenarios
• To improve marksmanship
• For reconnaissance training

Discussion

The objective of this research was to compare the effectiveness of rehearsing in a virtual environment versus rehearsing in a more traditional field setting. The two questions addressed by this research focused on whether skills acquired in the virtual environment transfer to the real world and how real-world performance differs as a function of the training site (i.e., rehearsal setting).

Transfer of Skills Acquired in the Virtual Environment to the Real World

One could argue that since the VE rehearsal group was able to rehearse in the identical building sections they would encounter in the real-world missions with a live OPFOR, real-world performance should be superior to that of the RW rehearsal group. This was not the case. Despite fewer rehearsal trials, no OPFOR, and rehearsing in a building that only approximated the building sections they would clear in the field (real world), the performance of the RW rehearsal group did not differ from that of the VE rehearsal group. The data show that VE rehearsal did not hurt real-world performance, but is equivocal as to how much transfer did take place.

Although no data was collected during the talk/walk and run rehearsal phases for both groups, data was collected for the two force-on-force missions conducted in the virtual-training environment. These two trials served as dress rehearsals for the VE rehearsal group. Performance during these two trials was comparable to the performance during the two missions

at the field-training site, particularly Mission 2 at the virtual-training site and the two field-training site missions.

However, the data seem to show that optimal performance was achieved somewhat quicker in the RW rehearsal condition. The primary reason the VE rehearsal group appeared to take longer to attain the same level of performance proficiency as the RW rehearsal group could be attributed to the lack of physical fidelity of the SVS systems, particularly in the areas of mobility, weapon system operation, and the lack of interaction with the virtual environment (inability to lean against walls, climb stairs, move stealthfully around corners, move obstacles, use hand and arm signals) most notably for Level II tasks.

The majority of the soldiers felt that a large component of urban operation training was the "hands-on" time required to physically rehearse such tasks as entering and clearing buildings, and the associated tactical/high precision movements. This perception was particularly strong with soldiers in this experiment since, as a collective group, they had little if any urban operation training and had never worked together as a cohesive small unit element.

It is interesting to note, however, that the talk/walk and run rehearsal phases for the RW rehearsal group were relatively brief (one hour for both phases) but "hands-on". This may have been enough time to familiarize them with the realistic task demands of the upcoming missions since both missions were fairly straightforward and did not require extensive planning.

In summary, using the criterion discussed earlier, VE rehearsal did not produce clear, positive transfer. Between group differences were relatively small for the most part. Group performance, as indexed by the weighted total scores, shows that even with some of the limitations listed above, the virtual rehearsals did not negatively impact performance.

Rehearsal time. As mentioned earlier, resource constraints required certain compromises in the design of the experiment. The number of rehearsals was limited to two for the RW rehearsal group and six for the VE rehearsal group (two talk/walk, two run, and two force-on-force rehearsals (virtual-training site Missions 1 and 2). Earlier research (see Nullmeyer & Spiker, 2000) indicated that increasing the amount of practice should result in improved performance. The maximum weighted total score attainable from the Evaluation Checklist was 135, so there was clearly room for improvement for both groups. Based on the final mission performance scores during the last mission, both groups had attained approximately 68 percent of the total points possible. Performance appeared fairly stable across missions (trials). Additional research is needed to determine how many trials are required to substantially improve performance from current levels and the cost/benefit of conducting extra trials at both the Virtual Simulation Lab and the McKenna training site. It would also be instructive to compare the performance patterns of the inexperienced squads used in this experiment with more experienced intact squads who have worked together with respect to learning rates and final proficiency scores.

It could be argued that the four additional rehearsals provided the RW rehearsal group was responsible, in part, for the similar levels of performance between the two rehearsal groups. Richardson, Montello and Hegarty (1999) found that when learning or rehearsal trials were

limited to one trial, that performance (spatial learning) was generally poorer for subjects who rehearsed in a virtual environment setting as opposed to those who rehearsed in a real-world environment. However, Ruddle, Payne, and Jones (1997) reported similar levels of performance (spatial learning) were obtained for subjects who rehearsed multiple times (10) in a virtual environment compared to those who rehearsed twice using a map. This research suggests that rehearsing in a virtual environment may require more trials to reach the same level of proficiency than is required for real-world rehearsals.

Real-World Performance Differences as a Function of Training Site

While the item weighting and scoring approach described earlier was useful in providing an overall picture of group performance, it did not allow for in depth comparisons of specific collective and individual tasks across groups and training sites. Some of the key task differences that were identified are discussed in the following sections.

Level III tasks. The number of casualties suffered by the four squads was high in both environments (real world and virtual). Analysis by casualty type (number OPFOR casualties, number of friendly casualties from OPFOR fire and fratricide) showed that fratricides were most responsible for group performance differences observed in these environments. All but one of the fratricides occurred during execution of the virtual environment missions. The majority of these fratricides were system related. The SVS system's way of "throwing" grenades was extremely awkward. The current way of throwing the grenade by timing the toss of the grenade using the weapon with a calibration figure on the screen was difficult to master in the time allotted to train this task. Also, when a soldier gets stuck in a wall, for example, if his grenade is armed, and the soldier executes the unstick command (using his weapon mounted thumb switch), the grenade drops and explodes, killing everyone in the immediate area.

Because of the manner in which grenades were thrown in the two environments was so dissimilar, there was no carryover to the real-world missions for the VE rehearsal group. The fratricide rate dropped to zero during the real-world missions for the VE rehearsal group. In contrast, when the RW rehearsal group executed the same missions in the virtual environment following their real-world missions, the fratricide rate jumped noticeably (one half of these fratricides were due to grenades). If this same grenade system is used in the future, more time will have to be allotted to training this task. The problems experienced by soldiers on this task clearly diminished the realistic feel of these virtual mission rehearsals.

From a more general standpoint, there are several possible reasons for the high number of casualties suffered by the squads in both environments. The scenarios involved a platoon attack which typically involves three squads. The manpower for this exercise was limited to either a 7 or 9-man exercise squad. For practical and experimental reasons, the decision was made to continue the mission well beyond the standard criterion of combat ineffectiveness (loss of one fire team's worth of manpower), often to the extent of total attrition.

Another problem with the exercise was the force ratios (combat power including combat multipliers) between the OPFOR and the exercise squad. Typically, force ratios for an offensive operation in open terrain (terrain permitting unhindered movement) is 3:1 (three friendly soldiers

or effects of combat multipliers to one enemy soldier). Due to the nature of combat in built-up areas, more troops are normally needed than in other combat situations. In a built-up area, the requirement can be as much as "three to five times greater than for an attack in open terrain" [U. S. Department of the Army, 1999 (FM 90-10-1, pg. 9)].

As mentioned earlier, to preserve this ratio throughout as much of the mission as possible, the squad was allowed unhindered access off the stairwells, an obvious kill zone, and restrictions were placed on when the OPFOR could engage the exercise squad, i.e., not to fire on the exercise squad until the third man had deployed on that particular floor of the building. This restriction helped to some extent to enhance squad survivability and to counterbalance the limiting force ratio, but could not completely counter the lack of manpower. In summary, rehearsal site did not appear to have any real effect on the number of casualties suffered by each group.

Level II tasks. When only the real-world performance of the two rehearsal groups is considered, differences were very small. These differences were observed for only a subset of Level II tasks. Incident rates were highest for failure to properly clear rooms, maintain proper position for providing protective cover, place soldiers to provide supporting fires, and accurately report OPFOR location.

Performance differences (total number of incidents across tasks) at the field-training site were particularly noticeable at Mission 2. The incident rate for the VE rehearsal group was higher than that of the RW rehearsal group. Performance at the virtual-training site revealed the same incident pattern for both missions (more incidents observed for the VE rehearsal group than the RW rehearsal group. The overall incident pattern across all tasks appears to show that the RW rehearsal group's performance in the virtual environment benefited from their prior real-world experience. Prior virtual environment experience did not, however, lead to improved real-world performance, i.e., fewer negative incidents detected.

Why the virtual environment mission performance of the VE rehearsal group was so much poorer than the RW rehearsal group for the Level II tasks, particularly for room clearing, providing protective cover, and to a lesser extent providing supporting fire, is not clear. Given the small sample size, and the unexpected pattern of results, any explanation should be viewed cautiously.

Level I tasks. Of the six Level I tasks, personnel flagging accounted for the large majority of total incidents observed. Most of these personnel flaggings occurred in the virtual environment. This problem is primarily a function of SVS system constraints. Close, precise movements, such as moving around corners, crouching under windows while moving, and wall hugging are difficult to accomplish smoothly in the virtual environment. In order to move around corners, the soldier has to move further away from the wall than he would like, which causes him to silhouette himself in doorways. Also, the challenge of moving in a physically restricted area and then crouching and moving as one approaches a window is frequently overlooked as the soldier is too busy focusing on trying to move from one spot to another with his team. As a result, he silhouettes himself in the window. With regard to hugging walls,

insufficient numbers of body sensors on the soldier allows him to pass through a wall, frequently exposing his arms or legs on the other side of the wall. This makes him visible to the enemy.

The lower incident rate for the VE rehearsal group during the real-world missions could be due to their prior experience at the virtual-training site. However, at Mission 2, any residual experience effects were quite weak, since group performance differences were negligible.

Two Level I tasks accounted for the bulk of the remaining negative incidents that were observed, weapon flagging and succession of command not established. The only clear trend that emerged was for succession of command. Soldiers in the RW rehearsal group were more likely to not establish succession of command during the real-world missions as the VE rehearsal group. Group differences could be the result of an "adrenaline" factor of the impending real-world mission, where the squad/team leaders were so focused that they forgot to tell others of the succession of command. Apparently, for the VE rehearsal group, soldiers grasped the importance of this task after their first virtual-training mission. After that, errors dropped to zero with the next mission and stayed low during the field-training missions.

Soldier Comments on Using Virtual Environments for Mission Rehearsals

Soldiers who rehearsed in a real-world mission setting clearly liked the "hands-on" aspect of this training strategy. The real-world rehearsal allowed soldiers the chance to climb stairs, lean against walls, throw grenades, use hand signals, peek around corners, and move obstacles. The execution of these physical tasks, they felt, was critical for effective urban operation training. Soldiers also liked the added realism created by the simunition rounds. Getting shot with simunition rounds provided immediate feedback that the soldier had made a mistake and created a real incentive for him to take cover and move more tactically. In general, it enhanced the realistic feel of the field-training missions.

Although the physical execution of these tasks is an important part of the training/ rehearsal process, the data nevertheless show that some learning can take place in a virtual environment under far less realistic conditions. As noted by the soldiers, these environments can serve as a valuable training option for when the unit does not have access to real-world training sites. These environments provide a potentially effective means to conduct the "walk" phase of training. The real-world training sites can then be more efficiently used for the "run" phase of training where the unit gets the chance to physically execute the missions with a solid "blue print" for action.

While virtual environments were never meant to replace real-world training sites, efforts are needed to enhance the realism of at least the core aspects of these environments. The biggest complaint from soldiers concerned maneuverability. The inability to perform fine, precise movements near or within buildings in close proximity with others was a major source of frustration. While movement (in the SVS) will never duplicate real-world movement patterns, virtual movements can be made smoother and more precise. The source of much of this problem in movement has to do with the design of the thumb switch (Pleban et al., 2001; Pleban et al., 2000). As discussed in earlier work, the current thumb switch used in the SVS system is stiff and consequently it is very difficult to synchronize the amount and direction of pressure that is

applied to guide movement. The lack of play in the switch makes it very difficult to control precise movement patterns.

The "sticking" problem described earlier became a major issue in this experiment since the scenarios required so much movement on the soldiers' part. Sticking is primarily due to current system constraints that limit the number of body sensors that can be used on the soldier. Like the thumb switch problem, this is also correctable but will require additional computing power.

The building clearing scenarios required the use of grenades. However the use of grenades resorted in numerous fratricides during the execution of the virtual environment missions. The problems associated with "throwing" grenades in the SVS system have already been discussed. Ideally, a more realistic way of throwing grenades is needed. If this cannot be accomplished, then the procedures should be simplified, so the task can be mastered with minimal training.

Soldiers also reported problems using the on-screen menu. Up until this experiment, soldiers did not view menu design and function as a problem. Apparently, the design of the menu resulted in some soldiers missing the unstick option. This increased their exposure time to the enemy as they cycled through the menu a second time to locate the correct option. The scenarios may have accentuated this problem since they required extensive movement within buildings. This, in turn, increased the number of "sticking" incidents and highlighted possible menu design issues.

The limited FOV provided by the SVS system appeared to be more problematic in this experiment. Again, the scenarios may have exacerbated this shortcoming. Clearing rooms requires that the soldier's head be able to swivel, look up, down, side-to-side, etc. The limited peripheral vision and the manner required for soldiers to look to their side (using the thumb switch) negatively impacted their performance in these scenarios (from the soldiers' standpoint). For rapid, realistic changes in views, soldiers preferred a system that was based on head movements rather than the thumb switch.

It should be noted that the scenarios developed for this experiment required that squad members execute basic tactical behaviors such as moving inside buildings and throwing hand grenades. The problems observed were not so much a function of the scenarios as they were weaknesses in this simulation (SVS) system.

Both groups felt that training should be expanded but for different reasons. For the RW rehearsal group, soldiers felt that the time scheduled for rehearsals was too short. For the VE rehearsal group, rehearsal time appeared adequate, but the time allotted for familiarization of the SVS system was viewed as insufficient. The vast majority of soldiers in this experiment had little if any training in urban operations, so it is not surprising that they felt the rehearsal time was too limited. This is particularly the case for the RW rehearsal group which had only two rehearsal trials.

All soldiers felt that additional urban operations training time was needed prior to conducting the mission rehearsals. Time scheduling permitted only one hour of training in the basic skills, which was clearly not enough. This could account, in part, for the lowered total weighted scores achieved by each group.

In terms of improving rehearsals in general, some soldiers felt that it would be useful to rotate squad members through different leadership positions to develop an increased awareness of the various leadership demands placed on the squad and team leaders. This could be quite useful but would involve more rehearsal trials to rotate squad members through the different leader positions. This could be a problem, from both a time and cost perspective, particularly for real-world rehearsals.

Mission Rehearsal Effectiveness Ratings

The effectiveness ratings showed a clear bias that was dependent on the rehearsal setting. When asked if virtual environments could be used to conduct effective mission rehearsals, almost every soldier in the VE rehearsal group said yes. In contrast, less than half of the RW rehearsal group felt the same way. This was most likely due to the fact that the RW rehearsal group conducted no rehearsals in the virtual environment. Their exposure was limited to a familiarization period and the two missions. The major reason for bringing the RW rehearsal group back to the Virtual Simulation Lab was to provide them some experience in the virtual environment so they could make some comparisons between the two environments. For all intents and purposes, the critical baseline data was collected the first day of the experiment and soldiers knew they were not using the virtual-training site to rehearse an upcoming mission. The reduced exposure time to the virtual environment, and possibly lower incentive generated by this "supplemental training phase" may be responsible for the lower ratings provided by the RW rehearsal group. These factors may have also negatively affected their virtual performance on the Level I task, personnel flagging (increased number of incidents) during Mission 2.

Comparing the effectiveness ratings of the two settings, approximately one half of the soldiers in the VE rehearsal group felt that virtual environments were less effective than real-world settings for conducting mission rehearsals. In contrast, all soldiers in the RW rehearsal group said that virtual environments were less effective than real-world settings for conducting mission rehearsals. The "hands-on" factor played a major role in the shaping the ratings of the RW rehearsal group. When these soldiers moved to the virtual world on Day 2, the reality difference was clearly accentuated. This was a major consideration for soldiers, and most people were in agreement that certain simulated capabilities needed to be more realistic or at least function more smoothly.

Training in Virtual Environments

Virtual environments provide a vehicle for conducting training in a number of areas. While the capabilities of the VE hardware/software can affect both training utility and trainee perceptions, other factors may have more impact than pure fidelity. The overall training value of these environments ultimately depends on the quality of the scenarios, instructor effectiveness, and the soundness of the instructional approach. As Pleban et al. (2001) showed, well-crafted

scenarios coupled with an effective instructional strategy can so thoroughly immerse the soldier in the mission that many realism issues are overlooked, and significant learning can still be achieved. Lintern et al. (1989) further showed that physical fidelity is not a requirement for positive transfer. They argue that the more important challenge is enhancing the psychological fidelity or functional relevance of the simulation training environment.

There is a broad range of tactical skills that could be trained in the virtual environment. At one end of the continuum are the types of cognitive skills (decision-making) trained in the Pleban et al. (2001) experiment. This type of training does not require high fidelity, fast, or precise interface with the virtual world. Success in this instance is more likely to depend on the factors described above. At the other end of the continuum are the specific squad drills and tasks, like building clearing, which involve less decision-making, a lot of communication and coordination, but above all require rapid and precise positioning, movement and use of weapons (Knerr et al., 2003). This experiment addressed one of the most difficult virtual environment training problems. As Knerr et al. (2003) point out, virtual environment training of tasks such as "*Clear a building*" and "*Clear a room*" have shown the least improvement in terms of enhanced skill proficiency. While virtual environments show promise for this type of training, there are a number of interface and technology problems to overcome. Currently, virtual environments do not appear to be as effective as real-world tactical training for improving skills underlying specific small unit tasks or battle drills.

Conclusions

The results from this research, while preliminary, indicate that certain small unit (squad) dismounted infantry tasks can be rehearsed with some degree of success in a virtual environment. Field-training site performance of the virtual environment and the real-world rehearsal groups were comparable. For fratricides and personnel flagging, a disproportionate number of incidents were a direct function of the training site, i.e., simulator system constraints. The research presented showed that while virtual environment systems may be lacking realistic qualities in certain areas, they could be used effectively for certain types of training. Virtual environments could be used during the "walk" phase of training, for improving decision-making, situation awareness, communication and coordination skills. These environments, if used appropriately in conjunction with realistic field- exercises, could play a major role in enhancing the training of soldiers and small unit leaders.

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